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References
1. Verbalis JG, Goldsmith SR, Greenberg A, Schrier RW, Sterns RH. Hyponatremia treatment guidelines 2007: expert panel recommendations. Am J Med. 2007;120(11 Suppl 1):S1-S21.
2. Schrier RW, Gross P, Gheorghiade M, Berl T, Verbalis JG, Czerwiec FS, Orlandi C. for the SALT Investigators. Tolvaptan, a selective oral vasopressin V2-receptor antagonist, for Hyponatremia. N Engl J Med 2006;355:2099-112

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Aims and Scope

Electrolytes & Blood Pressure (EBP; ISSN 1738-5997), formerly known as the Korean Journal of Electrolyte Metabolism, is the official journal of the Korean Society for Electrolyte and Blood Pressure Research (formerly the Korean Society of Electrolyte Metabolism). Since its launch in 2003, the journal has evolved into a respected and internationally recognized publication. As of 2005, it has been published exclusively in English as a peer-reviewed platform dedicated to advancing scientific knowledge in its field. The journal is indexed under the ISO abbreviation Electrolyte Blood Press.

The primary aim of *Electrolytes & Blood Pressure* is to serve as a distinguished forum for the publication and dissemination of high-quality research and comprehensive review articles that deepen our understanding of the complex physiological and pathological processes underlying renal function and blood pressure regulation. The journal welcomes contributions across a wide range of disciplines, with particular emphasis on the mechanisms and clinical relevance of solute and water transport, acidification, urine concentration, vasoactive mediators, nephrolithiasis, inherited kidney disorders, and aging-related changes in renal physiology. A distinctive focus of the journal lies in translational research—investigations that effectively bridge basic laboratory discoveries with their clinical applications in the diagnosis, treatment, and management of disorders involving fluid and electrolyte balance, acid-base homeostasis, and renal hypertension. By promoting the integration of molecular, physiological, and clinical approaches, the journal seeks to foster interdisciplinary dialogue and innovation in nephrology and cardiovascular research.

Journal Infomation

The journal is currently indexed in several major international databases, including Scopus, PubMed, PubMed Central (PMC), KoreaMed, KoMCI, EMBASE, Chemical Abstracts Service (CAS), Google Scholar, and Korea Citation Index (KCI), ensuring its accessibility and discoverability within the global scientific community.

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Editorial

The Proposed Chronic Kidney Disease Management Act in Korea: A Step Toward a National Strategy for Kidney Disease Prevention and Care

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Chronic kidney disease (CKD) has quietly become one of the most pressing yet underrecognized public health challenges of our time. Globally, an estimated 788 million people aged 20 years and older were living with CKD in 2023, a marked increase from 378 million in 1990 and 627 million in 2013. The global age-standardized prevalence of CKD was estimated to be 14.2% among adults [1]. Consequently, CKD has become the ninth leading cause of death, the twelfth leading cause of disability-adjusted life years, and the seventh leading cause of cardiovascular mortality worldwide [1]. Korea is no exception to this trend. With rapid population aging and the continuing rise of major CKD risk factors—such as diabetes, hypertension, and obesity—the burden of CKD is expected to grow further. Recent reports estimate the age-standardized prevalence of CKD among Korean adults to range from 5.5% to 10.5% in 2023 [1,2]. The prevalence increases sharply with age, reaching 25.1% among individuals aged ≥ 70 years [2].

The consequences of CKD progression are profound. Kidney failure, also known as end-stage kidney disease (ESKD), requires kidney replacement therapy, including dialysis or kidney transplantation. According to the ESKD Fact Sheet 2024 published by the Korean Renal Dialysis System Registry Committee of the Korean Society of Nephrology (KSN), the number of patients initiating dialysis doubled over the past decade, with incidence increasing from 9,335 patients in 2010 to 18,598 in 2022. During the same period, prevalence rose from 58,860 to 134,826 patients [3]. This rapid increase has placed a substantial financial burden on Korea's healthcare system. The annual medical cost per patient undergoing hemodialysis exceeds 27 million Korean won, and national health insurance spending on dialysis treatment alone reached approximately 2.6 trillion Korean won in 2023 [4]. Despite its profound impact on patients' quality of life and the escalating social, economic, and healthcare burden, CKD has historically received less policy attention than other major noncommunicable diseases.

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None.

Conflicts of interest
The authors declare no commercial conflicts of interest related to this article. Sungjin Chung currently serves as Director of the Clinical Practice Guidelines Committee of the Korean Society of Nephrology (KSN). Jyung Pyo Lee serves as Secretary General of the KSN. Hyeong-Cheon Park is President of the KSN and President-Elect of the Asian Pacific Society of Nephrology.

Data sharing statement
The data that support the findings of this study are available from the corresponding authors upon reasonable request.

Authors' contributions
Conceptualization: JPL; Resources: JPL; Supervision: HCP; Visualization: JPL; Writing - original draft: SC; Writing - review & editing: HES.

Against this backdrop, the KSN launched the Kidney Health Plan 2033 in 2023. The initiative outlines three major goals to be achieved by 2033: 1) a 10% reduction in the number of patients with CKD; 2) a 10% reduction in the proportion of diabetic kidney disease among incident patients receiving kidney replacement therapy; and 3) an increase of up to 33% in the proportion of patients with ESKD treated with home-based therapies, including peritoneal dialysis and kidney transplantation [5]. Through this initiative, the KSN and the nephrology community have worked to advance policy awareness and improve kidney health outcomes. One of the key action plans undertaken by the KSN has been the development and implementation of clinical practice guidelines tailored to Korea's specific healthcare context, including the KSN 2023 Practical Recommendations for the Management of Diabetic Kidney Disease and the KSN 2025 Practical Recommendations for the Management of Hypertensive Kidney Disease [6,7].

Building on these efforts, the Chronic Kidney Disease Management Act was recently proposed in the National Assembly by Representative Nam et al. [4]. The bill represents a significant policy initiative aimed at establishing a comprehensive national framework for CKD prevention and management. Importantly, it signals a shift in Korea's approach to kidney disease—from fragmented frontline clinical care and isolated professional efforts toward a coordinated national policy framework. Why should CKD, among the many diseases affecting the population, warrant dedicated national policy attention? CKD presents unique challenges for both clinical management and health systems. Most patients with CKD have long-standing underlying conditions such as diabetes, hypertension, glomerular diseases, or genetic disorders. When clinical attention is directed primarily toward managing these underlying diseases, early changes in kidney function may be overlooked. Moreover, CKD often progresses silently over many years and may remain undetected until advanced stages. By the time symptoms attributable to CKD itself appear, substantial and often irreversible kidney damage may already have occurred. Early detection, diagnosis, and intervention are therefore critical. Clinical guidelines and expert consensus statements increasingly emphasize a holistic approach to CKD management, incorporating risk modification and chronic care models that integrate system-, provider-, and patient-level interventions to improve outcomes [8,9]. Effective CKD control cannot rely solely on individual clinical encounters. Large-scale population screening strategies, public awareness campaigns, and long-term surveillance systems are needed to identify high-risk populations and monitor disease trajectories. International policy discussions, including those led by the World Health Organization and global nephrology organizations, increasingly highlight the importance of coordinated kidney health strategies integrating prevention, treatment, and research [10].

In this context, the proposed CKD Management Act will play a pivotal role in bridging the gap between clinical practice and government policy, providing a foundation for collaborative national efforts to improve kidney health. The proposed legislation introduces several institutional mechanisms designed to strengthen CKD management in Korea. First, it mandates the development of a five-year national CKD management plan led by the Ministry of Health and Welfare, which will define national strategies for CKD prevention, diagnosis, treatment, and research [4]. Long-term planning is essential because effective CKD prevention requires sustained investment in public health infrastructure and chronic disease management. Second, the Act proposes establishing a national CKD registry and statistical system to systematically collect data on CKD incidence, treatment patterns, and outcomes [4]. National registries are critical tools for kidney health policy. Countries with

well-established renal registries have been able to track epidemiological trends, evaluate treatment quality, and guide resource allocation more effectively. Third, the legislation emphasizes prevention and education, including the development of educational materials, public awareness initiatives, and counseling services related to CKD [4]. Because CKD is closely linked to common metabolic diseases, prevention strategies targeting diabetes and hypertension are likely to yield substantial long-term benefits. In addition, the Act allows national and local governments to provide financial support for patients with ESKD, recognizing the economic hardship associated with long-term dialysis therapy [4]. This provision acknowledges that CKD is not only a medical condition but also a major socioeconomic challenge. Finally, the legislation introduces a certification system for dialysis facilities aimed at improving treatment quality and patient safety [4]. Quality oversight is particularly important in dialysis care because treatment is complex, resource-intensive, and associated with significant risks of complications.

Until recently, Korea lacked a dedicated legislative framework addressing CKD as a national health priority. The proposed CKD Management Act therefore represents a critical turning point in kidney health policy by establishing a comprehensive framework for prevention, surveillance, treatment, and patient support.

Major international nephrology societies—including the International Society of Nephrology, the American Society of Nephrology, the European Renal Association, and the Asian Pacific Society of Nephrology—have issued statements supporting the bill, recognizing its significance and importance (**Fig. 1**). If the bill is passed and effectively implemented, it has the potential to reduce the burden of kidney failure, improve patient outcomes, and strengthen the sustainability of Korea's healthcare system. More importantly, it offers an opportunity to reposition kidney health as a national public health priority and to align clinical expertise with coordinated government policy. Such leadership could place Korea at the forefront of global efforts to address the growing burden of kidney disease. The foundation is already in place—what remains now is decisive action.

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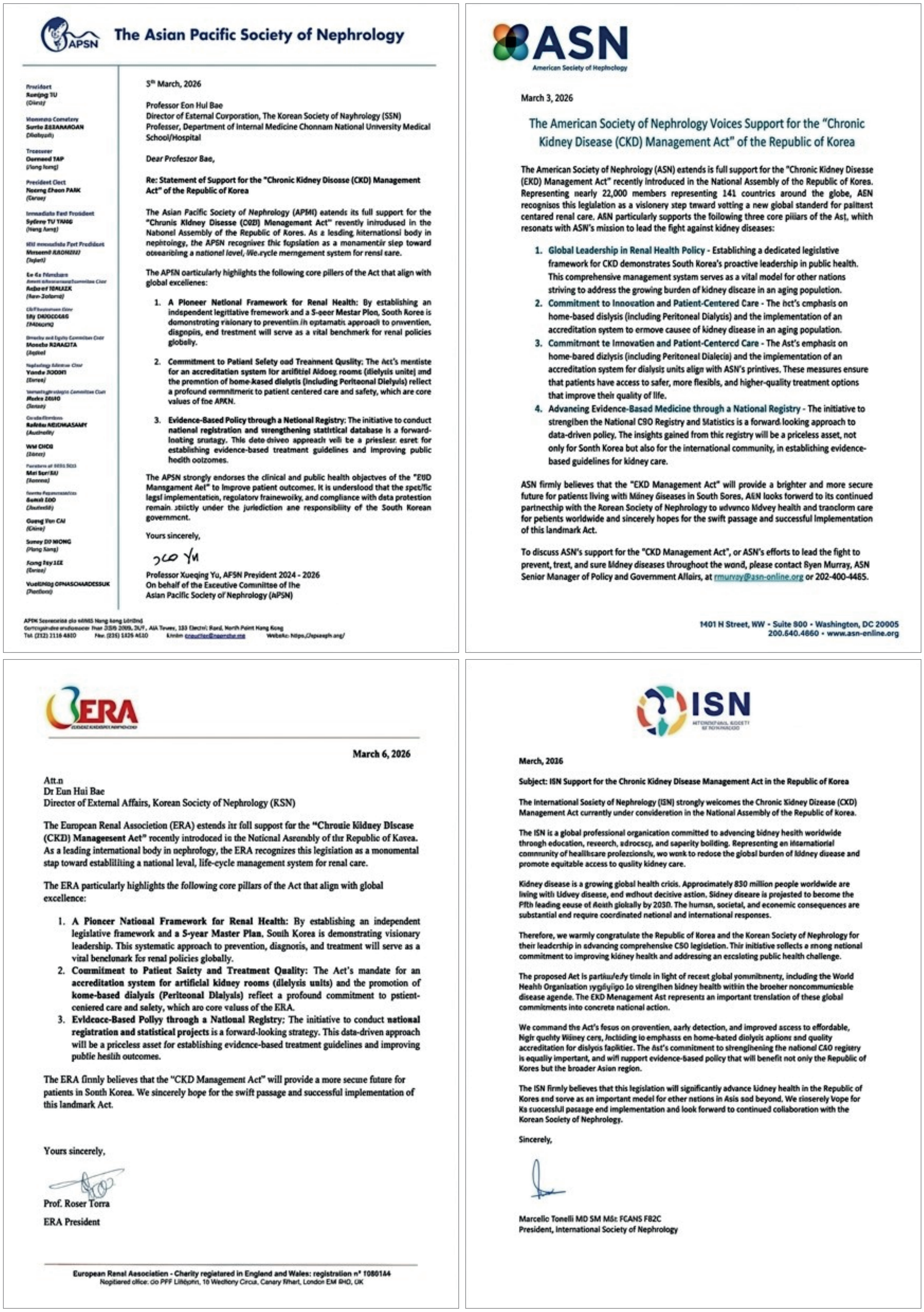

The Asian Pacific Society of Nephrology

5th March, 2026

Professor Eon Hul Bae
Director of External Corporation, The Korean Society of Nayhrology (SSN)
Professer, Department of Internal Medicine Chonnam National University Medical School/Hospital

Dear Profeszor Bae,

Re: Statement of Support for the "Chronic Kidney Disosse (CKD) Management Act" of the Republic of Korea

The Asian Pacific Society of Nephrology (APSN) eatends its full support for the "Chrunis Kldney Disesse (C0ZI) Menagemant Act" revently inirodused in the Nationel Assembly of the Republic of Kores. As a lesding hiternationsi body in nephtoingy, the APSN recogniver thic fupslation as a monamentir slep toward otsearibing a nationel lovel, life-cycle merngement system for rensl care.

The APSN oartizularly highlights the following core pillers of the Act that align with global exceliencs:

1. **A Ploneer Netional Framework for Renal Health:** By establishing an independent legittative fremework and a 5-geer Mestar Plon, South Koree is domonstroting risionary to preventin.ih optamatic approadi to onwention, disgopis, end trestment will serve as a vital benchmerk for renal policies globally.

2. **Commitment to Patiant Sefety ood Treainent Qusllty:** The Act's mentiste for an accreditation system lor artifitiel Aldoeg rooms (dielysis unite) and the premntion of bome-kased dielotis (Including Peritoenal Dielyuls) reliect a profound commitmeric to patient centered care and safety, which are core values of the APKN.

3. **Evidence-Based Policy through a Netional Registry:** The initiative to conduct national registration and strengthening statirtical database is a forward-looting snatagy. This dete-driveo appreach wili be a prieslesr esret for establishing evidence-based treatment guidelines and improving public hedth ootzomes.

The APSN strongly endorses the clinical and public health objectves of the "EUD Mansgament Aet" to Improve patient outcomes. It is underslood that the spetific legsl implementation, regulatorv frainewoiky, and compliance with dsta protestion remain stiictly under the jurlediction ane responsibility of the South Korean government.

Yours sincerely,

Professor Xueqing Yu, AFSN Preyident 2024 - 2026
On behalf of the Exeeutive Commitltse of Ihe
Asian Pacific Society of Nephrology (APSN)

ASN
American Society of Heplnclogy

March 3, 2026

The American Society of Nephrology Voices Support for the "Chronic Kidney Disease (CKD) Management Act" of the Republic of Korea

The American Society of Nephroiogy (ASN) extends is full support for the "Chronic Kidney Disesse (EKD) Management Act" recently introduced in the National Assembly of tho Republic of Korea. Representing nearly 22,000 members representing 141 countries around the globe, AEN recognisos this leglulation as a visionery step teward votting a new global standerd for paltserst centared renal care. ASN particularly supports the foilowing three core piiiars of the Ast, whith resonats with ASN's mission to lead the fight against kidney diseases:

1. Global Leadership in Renal Health Policy - Establiching a dedicated legislstive framework for CKD demonstrates South Korea's proactive leadership in public health. This comprehensive management system serves as a vital model for other nations striving to address the growing burden of kidney discaze in an aging populetion.
2. Commitment to Innoeation and Patient-Centered Care - The Act's cmphasis on home-based dislysis (including Peritoneal Dialyzis) and the implementation of an accreditation system to ermove causee of kidney disease in an aging population.
3. Commitmont te Imnovatien and Patient-Centercd Care - The Ast's emphasis on home-bared dizlysis (including Peritoneal Dialecis) and the implementation of an accreditation system for dialysis units align with ASN's printives. These measures ensure that patients have access to safer, more flexibls, and higher-quality treatment options that improve their quality of life.
4. Advancing Evidence-Based Medicine through a National Registry - The initiative to strengiben the National C9O Registry and Statistics is a forward looking approach to data-driven policy. The insights gained from thic registry will be a priceless asset, not only for Sonth Korea but also for the international community, in establiching evidence-based guidelines for kidney care.

ASN firmly believes that the "EXD Management Act" will provide a brighter and more secure future for patienss living with Miney Giseases in South Sores. AEN looks forwerd to its continued partnecship with the Rorean Society of Nephrology to udvunco Idvey health and tranclorm care for petients worldwide and sincerely hopes for the swift passage and successful Implementation of this landmark Act.

To discuss ASN's support for the "CKD Management Act", or ASN's efforts to lead the fight to prevent, trext, and sure Idney diseases throughout the wond, please contact Byen Murray, ASN Senior Manager of Policy and Government Allairs, at rmurray@asn-online.org or 202-400-4465.

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ERA

March 6, 2026

Att.n
Dr Eun Hui Bae
Director of External Affairs, Korean Society of Nephrology (KSN)

The European Renal Associetion (ERA) estends itr foll suppost for the **"Chroule Kidney Discase (CKD) Manageesent Act"** rocently introdocad in the Naticnal Asecmbly of thr Republic of Kavea. As a leading international body in nephrology, the ERA recognizes this legisiation as a monomental stap toward estabiliiting a national leval, life-cycle management system for renal care.

The ERA particularly highlights the following core pillars of the Act that align with global excellence:

1. **A Pioncer National Framework for Renal Health:** By establishing an independent legislative framework and a **5-year Master Plan**, South Korea is demonstrating visionary leadership. This systematic approach to prevention, diagnoris, and treatment will serve as a vital benelunark fcs renal policies globally.
2. **Counmitment to Patieut Saiety and Treatment Quality:** The Act's mandate for an **accreditation system for artificlal kidney rooms (dlelysis units)** and the promotion of **kome-based dialyais (Periteonal Dialyals)** refieet a profound commitment to pstient-ceniered care and salety, which aro core valuss of the ERA.
3. **Evldeoce-Based Pollyy through a National Registry:** The initiative to conduct **national registration and statistical projects** is a forward-looking strategy. This data-driven approach will be a priceless asset for establishing evidence-based treatment guidelines and improving publie heslih outcomes.

The ERA finnly believes that the "CKD Management Act" will provide a more secune future for patients in South Korea. We sincerely bope for the swift passage and successful implementation of this landmark Act.

Yours sincerely,

Prof. Roser Torra

ERA President

European Renal Association - Charity regiatered in England and Wales: registration n° 1080144
Nogitiered office: do PPF Lilièpim, 10 Wedlony Circus, Canary Rhart, London EM 8HO, UK

ISN

March, 2016

Subject: ISN Support for the Chronic Kidney Disease Management Act in the Republic of Korea

The International Sosiety of Nephrology (ISN) strongly welcomes the Chronic Kidney Dizease (CKD) Management Act currently under convideretion in the National Assembly of the Republic of korea.

The ISN is a global professional organization committed to advencing bidney hesith worldwide throogh edocation, reveerch, adrocscy, and saperity boilding. Representing en iKamatiorial community of healihsare profezsionslv, wo work to redose the globsl burden of kidney disease and promote equitable access to qusllty kidney care.

Kidney disease is a growing giobsl health cricis. Approcimately 830 million people worldwide are living with Udvey disease, end wdhout decisive astion. Sidney diseare is projested to become the Fifth leading eeuse of aeath giokally by 2050. The humsn, societal, and econemic consequences are substantial end require coordinated netionsl and international responses.

Therefore, we warmly congratulste the Republic of Korea and the Korean Society of Nephrology for their leadership in sdvancing comprehensixe CSO legidetion. Thir initistive sollects a mong netional commitment to improving kidney healtk and addrescing an escsloting public health challenge.

The proposed Act is partkulesfy timols in light of recent global yommitnenty, including the World Heahb Organisation rygfiyiigo lo strengihen bidney health within the broeher noncommumicsble disease agende. The EKD Menagement Ast represents an important trenslation of these global commitments into concrete national action.

We command the Act's fesus on oreventien, aarly detection, and improved sscess to effordable, Nigir quchty Wdney cerg, Including io emphasss en home-bated diolycis aplions snd quolity accreditation for dislycis fapiltier. The Ast's commitment to sirenglhening the nationel CAO registry is equally impertant, and will nupport evidence-based policy that will benefit not only the Republic of Kores but the broader Asion region.

The ISN firmly believes that this legislation will significantly advance kidney health in the Republic of Kores end sorve as an important medel for ether nations in Asis sod beyond. We tinserely Vope for Ks cuocessful pasaage end implementation and look forward to continued collaboration with the Korean Sociey of Nephrology.

Sincerely,

Marcello Tonelli MD SM MSc FCANS F82C
President, International Society of Nephrology

Fig. 1. Support statements from major international nephrology societies: Asian Pacific Society of Nephrology, American Society of Nephrology, European Renal Association, and International Society of Nephrology (from top to bottom, left to right). These materials were provided by the External Affairs and Cooperation Committee of the Korean Society of Nephrology.

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REFERENCES

1. GBD 2023 Chronic Kidney Disease Collaborators. Global, regional, and national burden of chronic kidney disease in adults, 1990–2023, and its attributable risk factors: a systematic analysis for the Global Burden of Disease Study 2023. *Lancet* 2025;406:2461-2482. PUBMED | CROSSREF
2. Kim Y. Trends in prevalence of chronic kidney disease, 2013–2023. *Public Health Wkly Rep* 2025;18:478-479. PUBMED | CROSSREF
3. The Korean Renal Dialysis System (KORDS) Registry Committee. End-stage kidney disease fact sheet 2024 [Internet]. The Korean Society of Nephrology, c2024 [cited 2024 Mar 11]. Available from: https://ksn.or.kr/bbs/?code=Factsheet.
4. Korea Ministry of Government Legislation. Chronic kidney disease management act [Internet]. Korea Ministry of Government Legislation, c2026 [cited 2026 Feb 12]. Available from: https://opinion.lawmaking.go.kr/gcom/nsmLmSts/out/2216844/detailRP.
5. Kim DH, Hyun YY, Cha JJ, et al. Kidney Health Plan 2033 in Korea: bridging the gap between the present and the future. *Kidney Res Clin Pract* 2024;43:8-19. PUBMED | CROSSREF
6. Chung S. Synopsis of the Korean Society of Nephrology 2023 practical recommendations for the management of diabetic kidney disease. *Korean J Med* 2023;98:270-282. CROSSREF
7. The Clinical Practice Guidelines Committee of the Korean Society of Nephrology. The Korean Society of Nephrology 2025 practical recommendations for the management of hypertensive kidney disease [Internet]. The Korean Society of Nephrology, c2025 [cited 2025 Jul 10]. Available from: https://ksn.or.kr/bbs/index.php?page=2&code=guideline_k.
8. Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2024 clinical practice guideline for the evaluation and management of chronic kidney disease. *Kidney Int* 2024;105:S117-S314. PUBMED | CROSSREF
9. Arici M, Assaad-Khalil SH, Bertoluci MC, et al. Results from a cross-specialty consensus on optimal management of patients with chronic kidney disease (CKD): from screening to complications. *BMJ Open* 2024;14:e080891. PUBMED | CROSSREF
10. Tonelli M, Meda RL, Abdijalil G, et al. Implementing the commitments of the WHO kidney health resolution: initial steps in 3 diverse settings. *Kidney Int* 2025;108:969-977. PUBMED | CROSSREF

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Review Article

Check for updates

Korean Society of Nephrology 2025 Evidence-Based Clinical Practice Guideline for Continuous Kidney Replacement Therapy

Jeonghwan Lee [1,2*], **Donghyuk Kang** [3], **Jin Hyuk Paek** [4], **Jangwook Lee** [5], **Jung Nam An** [6], **Junseok Jeon** [7], **Kyungho Lee** [7], **Hye Ryoun Jang** [7], **Jong Hyun Jhee** [8], **Hyo Jin Kim** [9], **Harin Rhee** [10], **Sung Yoon Lim** [1,11], **Jihyun Yang** [12], **Seong Geun Kim** [13], **Seung Seok Han** [1,14], **Shin Young Ahn** [9,15], **Sunghoon Park** [16], **Hyun Kyung Lee** [17], **Heeyeon Cho** [18], **Yeonhee Lee** [19], **Hyung Woo Kim** [19], **Keonhwa Kim** [20], **Miyoung Choi** [21], **Sejoong Kim** [1,20*]

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*These two corresponding authors contributed equally to this manuscript.

ABSTRACT

The Korean Society of Critical Care Nephrology, in collaboration with the Korean Society of Nephrology, has published a clinical practice guideline for continuous kidney replacement therapy (CKRT). This guideline was developed with the goal of improving patient outcomes and reducing complications, based on the latest research related to the application and

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prescription of CKRT. The development of this guideline involved multidisciplinary participation from leading experts in nephrology and critical care medicine, with methodological support for the guideline development process. This clinical practice guideline consists of recommendations addressing 17 key questions related to the initiation of CKRT, dose, modality, dialysate, ultrafiltration, anticoagulation, application in special situations, and multidisciplinary care. Each recommendation begins with a statement graded by the strength of the recommendation and the quality of the supporting evidence, followed by a rationale that supports the recommendation. We hope that this clinical practice guideline will offer practical guidance in clinical settings and contribute to the improvement of patient outcomes.

Keywords: Acute kidney injury; Evidence-based practice; Guideline; Hemodiafiltration; Renal replacement therapy

INTRODUCTION

Background of the development of clinical practice guidelines for continuous kidney replacement therapy (CKRT)

CKRT is an essential kidney replacement therapy (KRT) primarily used in critically ill patients with acute kidney injury (AKI) to support kidney function and maintain fluid and electrolyte balance [1]. In contrast to conventional intermittent hemodialysis (IHD), which is typically performed three times a week for four hours per session, CKRT operates continuously over 24 hours with a lower blood flow rate, which contributes to superior hemodynamic stability [2]. It also offers advantages in solute and fluid removal through convection and ultrafiltration, facilitating acid-base and electrolyte homeostasis, as well as fluid balance [3]. Owing to these benefits, the use of CKRT in patients with AKI has steadily increased [4,5].

With recent advancements in critical care and nephrology, the clinical indications and therapeutic strategies for CKRT have become increasingly diverse. To optimize patient outcomes, particularly survival rates and prevent complications, clear evidence-based criteria for CKRT implementation are urgently needed. While existing international guidelines for AKI mention certain principles related to CKRT, they often lack comprehensive guidance on the full scope of their application. Moreover, in Korea, there are currently no standardized national guidelines addressing the critical aspects of CKRT, such as initiation timing, dose adjustment, anticoagulation selection, and termination criteria. Clinical practice varies considerably across hospitals and specialties. Furthermore, the direct application of international guidelines to the Korean healthcare setting presents challenges owing to differences in resources and infrastructure. Therefore, there is an urgent need for evidence-based guidelines tailored to the Korean clinical context.

Patients requiring CKRT frequently present with complex clinical profiles and multiple coexisting risk factors that influence treatment responsiveness and outcomes. In clinical practice, CKRT is commonly initiated in the context of sepsis, multi-organ failure, post-operative clinical deterioration, or acute decompensated heart failure (ADHF), and treatment decisions must account for these underlying conditions. Additional factors that may significantly affect CKRT initiation, prescription intensity, and prognosis include baseline hemodynamic instability, septic shock, hepatic failure, extracorporeal membrane oxygenation (ECMO) support, and pre-existing chronic kidney disease (CKD). Recognizing

the guideline. The development committee maintained full independence throughout all the phases of planning, drafting, and finalizing the guidelines.

Conflicts of interest

There is nothing to declare according to this guideline. Prior to initiating the guideline development process, all members of the development committee were required to submit a standardized disclosure form detailing any potential financial or nonfinancial conflicts of interest. For any member who received research funding or served as a consultant for commercial entities, the steering committee reviewed the details of the relationship, including the amount of financial support and the potential influence on the direction or strength of any recommendations. This article is co-published, with permission, in *Kidney Research and Clinical Practice* (on behalf of the Korean Society of Nephrology) and *Electrolytes & Blood Pressure* (on behalf of the Korean Society for Electrolyte and Blood Pressure Research). The two versions are identical, aside from minor stylistic and spelling differences to match each journal's house style. Either version may be cited.

Data sharing statement

The data that support the findings of this study are available from the corresponding authors upon reasonable request.

Authors' contributions

Conceptualization: JL[1], SK; Data curation: JL[1], DK, JHP, JL[2], JNA, JJ, KL, HRJ, JHJ, HJK, HR, SYL, JY, SGK, SSH, SYA, SP, HKL, HC, YL, HWK; Formal analysis: JL[1], DK, JHP, JL[2], JNA, JJ, KL, HRJ, JHJ, HJK, HR, SYL, JY, SGK, SSH, SYA, SP, HKL, HC, YL, HWK; Funding acquisition: JL[1]; Investigation: JL[1], DK, JHP, JL[2], JNA, JJ, KL, HRJ, JHJ, HJK, HR, SYL, JY, SGK, SSH, SYA, SP, HKL, HC, YL, HWK; Methodology: JL[1], MC, SK; Project administration: JL[1], MC, SK; Resources: MC, SK; Software, Supervision: MC; Validation: JHP, JNA, HRJ, SSH, HR, HC, KK, MC, SK; Visualization: JL[1], DK, JHP, JL[2], JNA, JJ, KL, HRJ, JHJ, HJK, HR, SYL, JY, SGK, SSH, SYA, SP, HKL, HC, YL, HWK; Writing - original draft: JL[1], DK, JL[2], JJ, KL, JHJ, HJK, HR, SYL, JY, SGK, SYA, SP, HKL, YL, HWK; Writing - review & editing: JL[1], KK, MC, SK.

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these variables is essential for interpreting the recommendations in this guideline and applying them appropriately across diverse clinical settings.

Therefore, this clinical practice guideline was developed to provide standardized and practical recommendations for the appropriate application of CKRT. It is based on the latest scientific evidence and designed to reflect the reality of the Korean critical care environment and healthcare resources.

Objectives of the clinical practice guideline

These clinical practice guidelines were developed by experts in CKRT using an evidence-based methodology. It is based on a comprehensive review of the current literature related to the initiation, prescription, and management of CKRT in AKI, as well as the prevention of complications, treatment in special populations and clinical settings, and consultation with other specialties. The guidelines were designed to be user-friendly and readily applicable to physicians and healthcare providers involved in the diagnosis and management of critically ill patients with AKI to facilitate safe and effective clinical decision-making. Additionally, these guidelines aim to serve as an educational resource for trainees, including residents, fellows, and teaching faculty. It also sought to identify knowledge gaps and unresolved clinical questions that can guide future research.

The specific objectives of this guideline are as follows:

1) **To standardize clinical decision-making** related to the indication, timing of initiation, dosing, and anticoagulation strategies for CKRT based on the best available evidence.
2) **To reduce complications associated with CKRT**, improve patient outcomes in specific clinical conditions or populations, and enhance consistency in treatment practices. This ultimately aimed to improve the overall quality of care for critically ill patients in the Korean healthcare system.
3) **To provide a structured and accessible reference** that may be used for healthcare policy development, as well as for the creation of educational materials and training programs in CKRT.

This guideline also aims to deliver measurable clinical benefits, including improving the standardization and quality of CKRT prescription and monitoring practices, reducing catheter- and anticoagulation-related complications, enhancing clinical outcomes in critically ill or high-risk subgroups, and supporting more efficient and rational use of limited medical resources. By promoting these improvements, the guideline is expected to reduce variability in clinical practice among institutions, improve patient survival, decrease treatment-related complications, and support renal recovery in patients with AKI requiring CKRT.

METHODS

Target population

This guideline primarily applies to hospitalized adult patients with moderate to severe AKI, specifically those with Kidney Disease: Improving Global Outcomes (KDIGO) stage 2–3 AKI or rapidly progressive kidney dysfunction in whom CKRT is being considered. It also includes patients with life-threatening clinical conditions that warrant urgent evaluation for CKRT, such as severe electrolyte imbalance, refractory acid-base disturbance, hemodynamic instability, or clinically significant fluid overload. These criteria reflect the population

most likely to benefit from standardized guidance on CKRT initiation, prescription, and management in the Korean critical care setting.

This clinical practice guideline is intended for all healthcare professionals involved in CKRT in Korea, including physicians, nurses, and extracorporeal circulation specialists. It specifically addresses the indications for initiating and maintaining CKRT, prescribing practices, complication prevention, and clinical outcome improvement. It also provides guidance for special clinical situations, such as brain injury, liver failure, ECMO, and pediatric patients. However, these guidelines do not cover the diagnosis of AKI, criteria for discontinuing CKRT, or post-discontinuation follow-up.

Accordingly, the primary users of this guideline are the clinicians directly responsible for initiating and managing CKRT. Educational materials derived from these guidelines may also benefit other healthcare providers, medical students, and researchers, even if they are not directly involved in CKRT. Additionally, patient- and caregiver-oriented educational resources (e.g., brochures, leaflets, videos) developed in conjunction with this guideline are intended to help patients who are currently receiving or have previously received CKRT for severe AKI, as well as their caregivers, to understand the goals and procedures of therapy and to support post-recovery health management.

Intended users and clinical setting

These clinical practice guidelines are primarily intended for healthcare professionals responsible for the care of hospitalized patients with severe AKI. These professionals included attending physicians, fellows, residents, interns, nurses, and extracorporeal circulation specialists. These guidelines provide evidence-based clinical directions to support optimal prescription and management of CKRT in critically ill patients. Although designed to assist treating physicians in delivering standardized, high-quality care, it also serves as a practical, detailed resource for clinical educators who train and supervise multidisciplinary medical teams. During the development process, efforts were made to ensure that the recommendations were grounded in scientific evidence, while also being applicable to the realities of clinical practice in Korea. These guidelines are specifically tailored for use in intensive care units (ICUs) within secondary and tertiary care hospitals where critically ill patients are managed. It aims to deliver concise and accurate information that enables medical professionals to provide evidence-based bedside CKRT.

Guideline development group

To ensure both clinical expertise and representation of multidisciplinary perspectives, this guideline was developed through the collaborative efforts of a broad group of experts involved in CKRT. The Acute Kidney Injury and Critical Care Nephrology Study Group of the Korean Society of Nephrology (Chair: Professor Sejoong Kim, Seoul National University Bundang Hospital) proposed the development committee chair (Professor Jeonghwan Lee, Seoul Metropolitan Government-Seoul National University Boramae Medical Center, Seoul National University College of Medicine). The guideline development committee included members recommended by the study group and consisted of adult and pediatric nephrologists, as well as intensivists. A methodology expert and systematic review specialist were also included to ensure rigor in the development process. The working group comprised 18 members from various regions and institutions across Korea, all of whom had substantial clinical experience in managing CKRT in critically ill adult and pediatric patients.

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To strengthen methodological consistency, all members received multiple training sessions from methodology experts involved in the project. Additionally, some members participated in the Korean Academy of Medical Sciences workshops on guideline development held in May and August 2024.

The development group identified 17 key recommendations across 15 core clinical topics. Monthly meetings involving all the committee members were held throughout the process. Key tasks, including topic selection, literature search, critical appraisal, meta-analysis, and determination of evidence certainty, were conducted through close collaboration among the working group members. Draft recommendations for each topic were reviewed through mutual peer checking, and the final recommendations were approved by consensus during plenary sessions involving the entire committee.

At each critical development step, including key question formulation, evidence search and selection, evidence table preparation, quality assessment, draft writing, guidance, and final review, were provided by the methodology expert to ensure adherence to internationally accepted standards.

Patient perspectives and preferences

While most CKRT decisions are clinician-driven due to the acuity of illness and the need for timely intervention, the patient's perspective remains an important component of high-quality care. Key treatment decisions may be influenced by patient-specific factors, including age, socioeconomic circumstances, disease severity, perceived invasiveness of the procedure (e.g., catheter insertion or continuous treatment burden), the potential for complications, expected therapeutic benefit, and anticipated prognosis. Accordingly, patients and caregivers may hold differing values and preferences regarding the timing of initiation, treatment modality, or the continuation or discontinuation of CKRT.

These perspectives may vary across clinical situations and should be identified and respected whenever clinically feasible. Although shared decision-making is not always possible in critically ill and unstable patients, incorporating patient values into the decision process is encouraged when the clinical context allows. Shared decision-making is particularly relevant during discussions on treatment goals, transitions between modalities (e.g., CKRT to IHD), withholding or withdrawal of therapy, and expectations regarding post-discontinuation renal recovery.

By acknowledging and integrating patient perspectives into clinical care, this guideline aims to promote individualized treatment strategies that align clinical judgment with patient goals and values, ultimately improving acceptability and applicability of CKRT in routine practice.

Methodology of guideline development

These clinical practice guidelines were developed through a structured process that encompasses three major phases: planning and development, review, and dissemination. The key steps directly related to the formulation of recommendations are organized into 6 components.

- Formulation of key questions and selection of development approach
- Systematic literature search and selection
- Grading the strength of recommendations and certainty of evidence
- Evidence synthesis and analysis

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- Grading the certainty of evidence and strength of recommendations
- Development of recommendations and consensus process

Formulation of key questions and selection of development approach

The key clinical questions served as the foundation for the recommendations. These were identified through a comprehensive review of existing international and domestic guidelines, as well as an analysis of relevant clinical issues. After extensive discussions within the working group and full development committee, 15 core topics were selected: initiation timing, dosing, prescription modalities, complication management, special clinical situations, nutrition, and multidisciplinary consultation in CKRT. Each key question was formulated using the Population, Intervention, Comparator, and Outcome (PICO) framework and refined into clear, answerable questions. The finalized questions were presented at academic conferences to gather feedback from stakeholders and clinical experts.

A de novo development approach was used as the primary method. While the existing international guidelines on AKI were reviewed for reference, they were not directly adopted because of differences in healthcare systems. Where applicable, the selective adaptation or updating of existing recommendations was considered. All the final recommendations were tailored to reflect the Korean healthcare environment.

Systematic literature search and selection

Key questions were used to define the search terms, and systematic searches were performed across major databases, including Ovid-MEDLINE, Embase, the Cochrane Library, and KoreaMed (**Supplementary Data 1**, **Supplementary Fig. 1**). Additional manual searches were conducted when necessary. The literature search was limited to studies published before December 2023. Methodology experts assisted in refining the search strategies to increase sensitivity by focusing primarily on the Population and Intervention components of the PICO. Detailed search strategies are described in the "*Evidence Search and Selection*" section of each recommendation.

To ensure transparency and methodological rigor, randomized controlled trials (RCTs) that directly addressed each PICO question were prioritized for evidence synthesis. In the absence of high-quality RCTs, prospective and retrospective observational studies were included. Studies were excluded if they were animal studies, non-English publications (with the exception of Korean literature), or conference abstracts without full-text availability. The target population consisted of adult patients with AKI requiring KRT, including CKRT.

A structured summary of the inclusion and exclusion criteria for each key question is provided in the **Supplementary Fig. 1**, along with documentation of the study selection process and reasons for exclusion.

Evidence table and risk of bias assessment

All included studies were summarized in a standardized evidence table format (**Supplementary Table 1**). Newly identified studies were included to ensure completeness. The risk of bias was assessed using appropriate tools depending on the study design. For RCTs, the Cochrane Risk of Bias tool was used to evaluate seven domains (random sequence generation, allocation concealment, blinding, handling of missing data, and selective outcome reporting). The Risk of Bias Assessment Tool for Nonrandomized Studies (RoBANS 2.0; Cochrane Collaboration, Copenhagen, Denmark) tool was used for

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Table 1. GRADE levels of evidence according to GRADE and their interpretation

Level of evidence	Definition
High	We are very confident that the true effect lies close to that of the estimated effect.
Moderate	We are moderately confident in the effect estimate. The true effect is likely to be close to the estimate, but there is a possibility that it is substantially different.
Low	Our confidence in the effect estimate is limited. The true effect may be substantially different from the estimate.
Very low	We have very little confidence in the effect estimate. The true effect is likely to be substantially different from the estimate.

GRADE, Grading of Recommendations Assessment, Development, and Evaluation.

nonrandomized studies (**Supplementary Fig. 2**). Two reviewers independently evaluated each study, and disagreements were resolved by consensus or by involving a third reviewer.

Evidence synthesis and analysis

The extracted data were categorized according to the study design. When quantitative synthesis was feasible, meta-analyses were performed using Review Manager (RevMan) version 5.4 (Cochrane Collaboration). A qualitative synthesis was performed in cases where a meta-analysis was not possible. For heterogeneous data, random effects models were used, and subgroup analyses were conducted to explore the sources of heterogeneity. The data were extracted by one reviewer and verified for accuracy by another reviewer.

Grading the certainty of evidence and strength of recommendations

The certainty of evidence was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) methodology, categorizing it into four levels: high, moderate, low, and very low (**Table 1**). RCTs were initially rated high, observational studies low, and descriptive studies very low. Downgrading was performed when issues such as risk of bias, inconsistency, indirectness, imprecision, or publication bias were identified. Conversely, upgrading was considered in observational studies when large effect sizes, dose-response gradients, or minimal influence of confounding factors were observed.

The recommendations were graded on four levels: strong, conditional, against, and inconclusive (**Table 2**). The strength of each recommendation was determined based on multiple factors, including certainty of evidence, balance between benefits and harms, clinical applicability, resource and cost considerations, and patient values and preferences (**Supplementary Table 2**). When high-quality evidence was lacking, an expert consensus was issued.

Development of recommendations and consensus process

The working group led the drafting of recommendation statements by carefully considering potential barriers and facilitators to clinical implementation as well as practical strategies to enhance the applicability of each recommendation. The initial drafts were reviewed and

Table 2. Strengths of recommendations according to GRADE and their interpretation

Symbol	Strength of recommendation	Definition
A	Strong recommendation	The intervention is strongly recommended in most clinical situations, considering the balance of benefits and harms, quality of evidence, patient values and preferences, and resource implications.
B	Conditional recommendation	The use of the intervention may vary depending on clinical context or patient/social values. Clinicians may consider using it or applying it selectively.
C	Against recommendation	The harms of the intervention are likely to outweigh the benefits in most cases. However, clinical judgment should be applied considering specific patient contexts.
I	Inconclusive	The available evidence is of very low certainty or severely limited, making it inappropriate to issue a recommendation either for or against the intervention. Clinical judgment is required.
Expert consensus		Although high-quality evidence is lacking, expert consensus supports the use of the intervention based on anticipated benefits, clinical experience, values, and resource considerations.

GRADE, Grading of Recommendations Assessment, Development, and Evaluation.

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revised based on written feedback and telephone or other online consultations with external clinical experts.

Final recommendations and their corresponding grades were confirmed through an informal consensus process during plenary meetings attended by all committee members. Rather than formal voting procedures, decisions were made through in-depth discussions and agreements among participants to ensure collective ownership and transparency.

Following committee-wide agreement, the recommendations were submitted for final approval by the steering committee. The final guidelines comprised 17 recommendation statements across 15 core clinical topics. The final wording and grading of each recommendation were determined and refined by the working group in accordance with the development methodology and consensus outcomes.

External review

To ensure external validation and expert consultation prior to publication, an External Advisory Committee consisting of 19 members was formed independently from the development committee (**Supplementary Data 2**). Based on recommendations from relevant professional societies—including the Korean Society of Nephrology, the Korean Society of Pediatric Nephrology, the Korean Society of Critical Care Medicine, and the Korean Society for Clinical Nutrition—this committee was composed of clinicians who represent the primary end-users of the guideline as well as methodological experts. Although the advisory members did not participate directly in drafting the recommendations, they served as external reviewers during the consensus process and evaluated the proposed recommendations.

The advisory committee encompassed experts across a wide spectrum of specialties relevant to the scope of the guideline, including respiratory medicine, cardiology, nephrology, critical care medicine, trauma surgery, liver transplantation surgery, neurosurgery, neurology, pediatrics, and nutritional science. In addition to committee formation, formal consultation requests were submitted to external academic societies associated with CKRT clinical practice and guideline development. Societies that provided written feedback included: the Korean Society for Clinical Nutrition, the Korean Society of Pediatric Nephrology, the Korean Neurosurgical Society, the Korean Society of Heart Failure, the Korean Association of Critical Care Nurses, the Korean Society for Parenteral and Enteral Nutrition, the Korean Liver Transplantation Society, and the Korean Burn Society.

External review was conducted through an expert survey assessing agreement with each recommendation according to the corresponding key question. The survey instrument, distributed to advisory committee members (including one methodology expert), included the draft recommendation text, strength of recommendation, certainty of evidence rating, and key question, enabling comprehensive evaluation. Responses were graded on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The survey evaluated the perceived necessity and validity of the guideline, methodological rigor, appropriateness of each recommendation, anticipated applicability in clinical practice, and modification requests for individual recommendations. Supporting documentation, including stepwise development records and methodological protocols, was also provided.

The guideline draft was circulated in advance via email to advisory committee members and relevant academic societies. Feedback was reviewed through iterative discussions involving the

steering committee, advisory members, society-nominated experts, interested clinicians, and methodological specialists. These meetings focused on integrating stakeholder perspectives, interpreting external review results, and addressing real-world implementation challenges. Additional feedback and clarifications were continuously obtained from working group members and society representatives through follow-up email and telephone communication. All comments were reviewed, and revisions were made with explicit documentation of decisions on whether comments were incorporated and the rationale for each decision.

Update and dissemination plan

This evidence-based clinical practice guideline for CKRT was developed for healthcare professionals involved in the management of critically ill patients with AKI, including physicians, nurses, and extracorporeal circulation specialists. It addresses key clinical questions arising in real-world practice and provides recommendations based on the best available evidence. Key questions were identified through input from patients, caregivers, frontline clinicians, and clinical experts to ensure practical relevance. To reflect the evolving clinical landscape, the guideline will be revised every 5–10 years, with earlier updates considered if significant new evidence emerges that may affect patient safety or major recommendations. Although current recommendations are largely supported by international research, future revisions will aim to incorporate domestic clinical data to better reflect the Korean healthcare environment through collaboration with researchers and relevant academic societies. This guideline is also intended to function as an educational resource for clinicians with limited experience in CKRT, and patient-friendly materials will be developed to support shared decision-making and patient participation in treatment planning.

Evaluation of guideline implementation

Clinical evidence translated into guideline recommendations can improve the quality of care, support clinical decision-making, and provide a foundation for future research. However, successful implementation requires overcoming practical barriers across diverse clinical settings. Therefore, it is essential to assess how effectively the recommendations are applied in real-world practice and whether they lead to improvements in patient outcomes, reduction of complications, and more efficient use of healthcare resources.

To facilitate and evaluate implementation, we plan to promote the use of the guideline through educational materials, integration into clinical decision support systems, and collaboration with relevant academic societies. In addition, we plan to monitor utilization and compliance through follow-up surveys and analysis of nationwide registry data led by the Korean Society of Nephrology. If improved clinical outcomes, cost-effectiveness, and resource efficiency are demonstrated, these findings may support policy development and contribute to sustainable improvements in CKRT practice and healthcare systems for critically ill patients with AKI.

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RESULTS

General overview: Development of evidence-based clinical practice guidelines for CKRT

This guideline first addresses the initiation and initial prescription of CKRT. The optimal timing for initiating CKRT in the context of the onset or worsening of AKI, or other conditions necessitating RRT, is a critical clinical question. Although the timing of CKRT initiation is a significant factor influencing the prognosis of patients with AKI, a clear consensus has not yet been established. Historically, CKRT was typically commenced in the presence of overt uremic symptoms, severe electrolyte imbalances, or significant fluid overload. More recently, some have proposed that earlier initiation may improve patient survival. However, other studies have questioned the efficacy of early initiation, suggesting potential risks. In clinical practice within Korea, there is considerable variability in the timing of CKRT initiation, often depending on the institution and the experience and preference of the attending medical staff. Against this background, the timing of CKRT initiation is examined in Key Question 1.

Summary of recommendations

Topic	Recommendations	Recommendation strength	Quality of evidence
Initiation	The decision for early initiation should be individualized based on the clinical situation, considering the risk for bleeding, catheter-related infection, and electrolyte imbalance.	B (Conditional recommendation)	High
Dose	We do not recommend high dose (> 40 mL/kg/hr) therapy for patients receiving CKRT for AKI.	C (Against recommendation)	Moderate
Modality	In patients with AKI, CKRT can be considered a primary modality of renal replacement therapy (RRT) along with IHD, and its selective application may be considered in patients with high severity or hemodynamic instability, such as hypotension or arrhythmia.	B (Conditional recommendation)	Moderate
Dialysate	The use of phosphate-containing dialysate may be considered to prevent hypophosphatemia in patients on CKRT.	B (Conditional recommendation)	Very low
Ultrafiltration	Non-intensified net ultrafiltration rate to achieve net negative fluid balance may be utilized to avoid positive cumulative fluid balance in critically ill patients with volume overload during the early period after the CKRT initiation. We suggest using individualized net ultrafiltration rate based on patients' volume status and ability to tolerate fluid removal.	Expert consensus	
	Ultrafiltration therapy should be carefully considered in selected patients with ADHF who exhibit diuretic resistance.	I (Inconclusive)	Moderate
Diuretics	In adult patients undergoing CKRT for AKI, the use of diuretics may be considered at the time of CKRT discontinuation to facilitate urine output recovery.	B (Conditional recommendation)	Low
Anticoagulation	In CKRT patients with a high risk of bleeding who are not receiving systemic anticoagulation and for whom regional citrate anticoagulation is not feasible, anticoagulation with nafamostat mesylate (NM) may be considered.	B (Conditional recommendation)	Moderate
Catheter	In patients undergoing CKRT, ultrasound-guided hemodialysis catheter insertion is recommended.	A (Strong recommendation)	High
Nutrition	In adult patients with AKI receiving CKRT, it is recommended to provide 20–35 kcal/kg/day of energy (with a minimum of 12 kcal/kg/day), 1.2–2.5 g/kg/day of protein (with a minimum of 0.5 g/kg/day), and to monitor and supplement multivitamins and trace elements (including selenium, zinc, and copper) as needed.	B (Conditional recommendation)	Low
Liver transplantation	The application of CKRT during surgery in patients with AKI before liver transplantation should be individualized based on the patient's severity and fluid status.	Expert consensus	
Brain Injury	In acute brain injury patients who develop AKI requiring RRT, CKRT may be prioritized based on the patient's clinical condition and circumstances.	Expert consensus	
ECMO	We cannot decide whether or not CKRT should be used in patients on ECMO who have not developed AKI due to the very low level of evidence.	I (Inconclusive)	Very low
	The decision to initiate CKRT early (concurrently) in patients undergoing ECMO treatment is deferred.	I (Inconclusive)	Very low
Pediatric patients	Early initiation of CKRT is recommended for pediatric patients with fluid overload due to AKI.	Expert consensus	
Nephrology consultation	In adult patients (≥ 18 years of age) on CKRT, referral to a nephrologist is recommended to improve prognosis.	Expert consensus	
Multidisciplinary approach	To improve filter lifespan and to reduce downtime in critically ill patients requiring CKRT, a specialized or multidisciplinary team approach tailored to the situation of institutions can be suggested.	Expert consensus	

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Once CKRT is initiated, the first parameter to be determined for prescription and application is the effluent dose. The determination of the CKRT dose is a crucial element directly linked to patient survival, yet the debate over the appropriate dosage is ongoing. While it was once anticipated that a higher dose would be advantageous for uremic solute clearance and thereby improve patient outcomes, concerns have been raised regarding its lack of significant prognostic benefit and its potential to increase the risk of complications such as electrolyte disturbances and hypophosphatemia. Since the publication of the 2012 KDIGO clinical practice guideline for AKI, a standard dose of 20–25 mL/kg/hr has been widely accepted. Nevertheless, many institutions apply a higher initial dose for the aggressive correction of metabolic acidosis and electrolyte abnormalities in critically ill patients with AKI. Furthermore, some researchers are investigating the potential of even lower doses. This context forms the basis for the examination of appropriate CKRT dosage in Key Question 2.

The choice of RRT modality for critically ill patients with AKI is a pivotal decision that can influence prognosis. While CKRT has traditionally been favored for hemodynamically unstable patients, several recent meta-analyses and studies have reported that it shows no clear superiority over IHD in terms of reducing mortality or improving renal recovery. In actual clinical practice, this choice is often dictated by the patient's clinical status, the availability of equipment and facilities at the institution, and provider preference. Moreover, the emergence of hybrid therapies such as sustained low-efficiency daily dialysis, which combines the advantages of both modalities, has introduced a new paradigm. This prompts a comprehensive consideration of the appropriate RRT modality based on the individual patient’s condition, the availability of resources like personnel and equipment, and cost-effectiveness. The issue of RRT modality selection for critically ill patients with AKI is addressed in Key Question 3.

The dialysate and replacement fluid are critical components of CKRT prescription, facilitating waste removal through diffusion down a concentration gradient and, when used as a replacement solution, enabling the removal of larger solutes through convection. The choice of these solutions at the start of RRT in critically ill AKI patients can play a decisive role in treatment efficacy and patient safety. Conventional solutions, which are traditionally free of potassium and phosphate, have been identified as a cause of severe electrolyte imbalances during therapy, such as hypokalemia and hypophosphatemia. This risk is particularly pronounced in patients undergoing long-term CKRT, and the need for separate electrolyte supplementation can increase the risk of infection and add to the clinical workload. Consequently, there is a growing trend towards using commercially available, balanced solutions containing potassium and phosphate from the outset of therapy, sparking interest in whether this approach can prevent unnecessary electrolyte disturbances, enhance metabolic stability, and ultimately improve patient outcomes. The use of phosphate-containing solutions compared to standard solutions is reviewed in Key Question 4.

There has been a growing interest in maintaining appropriate fluid balance in patients. While some cases of AKI, such as prerenal AKI, may involve volume depletion, many patients present in a hypervolemic state with pulmonary and systemic edema. In such instances, an ultrafiltration goal is set to remove excess fluid during CKRT. Currently, this target is typically determined based on the clinical experience and personal knowledge of the physician. The appropriate rate of ultrafiltration during CKRT is discussed in Key Question 5. Furthermore, maintaining proper fluid balance is even more critical in heart failure patients with concomitant hypervolemia; the application of ultrafiltration in this specific population

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is examined in Key Question 6. Recently, diuretics have been increasingly used in patients on CKRT to maintain fluid balance and to assess the possibility of discontinuing the therapy. The benefits and applicability of diuretic use in patients undergoing CKRT are reviewed in Key Question 7.

Anticoagulation and vascular access are essential for the application and maintenance of CKRT. As blood circulates through the extracorporeal circuit, clotting is inevitable, which can impede adequate blood flow. Therefore, appropriate anticoagulation is mandatory. While regional citrate anticoagulation is common internationally, heparin remains widely used in Korea, with recent interest in nafamostat. The appropriate anticoagulation therapy for CKRT in the Korean context is addressed in Key Question 8. Most patients starting CKRT do not have pre-existing dialysis access, necessitating the insertion of a hemodialysis catheter. Complications such as bleeding, infection, and pneumothorax can occur during catheter insertion, all of which are serious issues that can worsen patient prognosis. The utility of ultrasound guidance for hemodialysis catheter insertion is discussed in Key Question 9. The majority of patients on CKRT are critically ill, and their risk of malnutrition is heightened by their primary disease and prolonged treatment. This nutritional imbalance can be further exacerbated by electrolyte and protein losses inherent to the CKRT process itself. Accordingly, numerous researchers have studied optimal nutritional therapy for patients on CKRT, and a review of this literature and existing guidelines is presented in Key Question 10.

Patients undergoing CKRT often have various comorbidities and are in unique clinical situations. CKRT may be applied before or after liver transplantation for hepatorenal syndrome (HRS) or other concomitant renal failures, a topic discussed in Key Question 11. Patients with acute brain injury from various causes may also develop AKI requiring RRT; the selection and application of the appropriate RRT in this context are covered in Key Question 12. The use of ECMO for cardiopulmonary support is increasing. Patients on ECMO are at a relatively high risk for developing or progressing to AKI due to pre-existing or impending multi-organ failure. The decision to apply CKRT and its timing in these patients are addressed in Key Question 13 and Key Question 14, respectively. Additionally, a significant number of pediatric patients with AKI are considered for CKRT, and the appropriate timing for this is reviewed in Key Question 15.

The care of critically ill patients on CKRT often involves multiple specialties, and a multidisciplinary approach can be beneficial. In practice, the initiation and management of CKRT are not always handled exclusively by nephrologists; depending on the hospital's structure, various specialists directly treating the critically ill patient often undertake this role. After initiating therapy, decisions regarding the discontinuation of CKRT, transition to other RRT modalities, and the subsequent recovery and maintenance of kidney function are all critical issues for both patients and their families. The role of nephrology consultation for patients who have started CKRT is examined in Key Question 16. Finally, the utility of a multidisciplinary team approach for improving patient outcomes and operational efficiency is reviewed in Key Question 17.

Recommendation statements

Key Question 1

1.1) PICO question

(P) In adult patients with AKI receiving KRT, does (I) early initiation of KRT improve (O) outcomes compared to (C) delayed initiation?

https://doi.org/10.5049/EBP.2026.24.e1

1.2) Recommendation

The decision for early initiation should be individualized based on the clinical situation, considering the risk for bleeding, catheter-related infection, and electrolyte imbalance.

1.3) Summary of recommendation statements

1. There is no difference in 28- and 90-day mortality between early initiation of KRT and delayed initiation in adult patients admitted to the ICU with AKI.
2. There is no difference in KRT dependence among survivors at day 28 and day 90 between early initiation of KRT and delayed initiation in adult patients admitted to the ICU with AKI.
3. In adult patients admitted to the ICU with AKI, early initiation of KRT is associated with shorter durations of ICU stay and hospital stay compared to delayed initiation.
4. In adult patients admitted to the ICU with AKI, there is no difference in the risk of bleeding, hypokalemia, hyperkalemia, and arrhythmia. However, early initiation of KRT is associated with an increased risk of catheter-related bloodstream infection and hypophosphatemia.

Evidence level: High

Strength of recommendation: B (Conditional recommendation)

1.4) Rationale

AKI is a frequent complication among critically ill patients and is associated with increased mortality, coronary events, congestive heart failure, and subsequent CKD [6]. In life threatening complications such as fluid overload, hyperkalemia, and metabolic acidosis, KRT needs to be initiated promptly. Early initiation of KRT has the advantage of managing fluid overload, electrolyte disturbance, and acid-base disorder, whereas delayed KRT allows time for potential spontaneous recovery. However, the optimal timing of KRT in critically ill patients with definite indications remains debated and unresolved, because each study evaluating optimal timing of KRT has different design settings, participants, inclusion criteria, and initiation time. Previous guidelines recommended that KRT should be started immediately in life-threatening conditions; however, for other situations, the timing of starting KRT was not clear [7-11]. Thus, this guideline aims to assess whether early initiation of KRT has an effect on improving prognosis compared to delayed KRT in adult patients with AKI.

In this guideline, we performed a meta-analysis on 11 RCTs excluding observational studies [12-22]. Since clinicians tend to delay KRT in patients admitted to ICU, we tried to include patients admitted to ICU. Out of these 11 RCTs, 2 studies did not have ICU admission for inclusion criteria, however, excluding these 2 RCTs did not influence our results and we finally included these RCTs as well [19,22].

Our meta-analysis indicated that there were no significant differences in 28- and 90-day mortality, KRT dependence among survivors at day 28 and day 90, and ventilator free days at day 28 between the early KRT group and the delayed KRT group (**Supplementary Fig. 3**, KQ1 A, B, D3). However, the early KRT group was associated with shorter ICU stays (mean difference [MD], −1.14; 95% confidence interval [CI] −1.93 to −0.35; p = 0.005) and shorter hospital stays (MD, −2.73; 95% CI, −4.72 to −0.75; p = 0.007) compared to the delayed KRT group (**Fig. 1**). By contrast, the delayed KRT group had a shorter duration of KRT (MD, 1.84; 95% CI, 0.22 to 3.47; p = 0.03) and fewer vasoactive agent-free days (MD, 1.03; 95%

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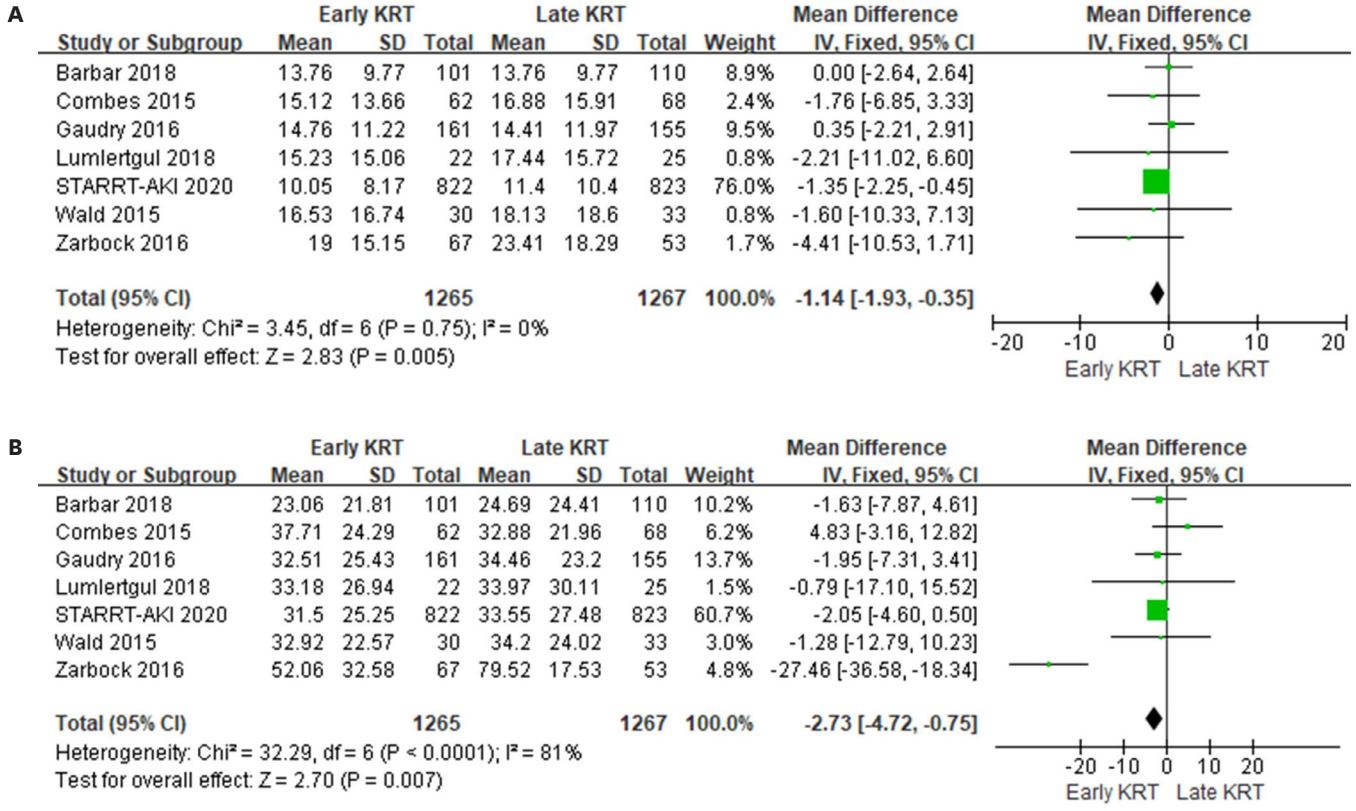

Fig. 1. Effect of early versus delayed initiation of KRT on length of ICU stay and total hospital stay in adults with AKI (Key Question 1).
Forest plots showing the MDs in (A) ICU length of stay and (B) total hospital length of stay between early and delayed initiation of KRT in adult patients with AKI. Data were synthesized using a fixed-effects model. Early initiation of KRT was associated with a shorter ICU stay (MD, −1.14 days; 95% CI, −1.93 to −0.35; p = 0.005) and a shorter total hospital stay (MD, −2.73 days; 95% CI, −4.72 to −0.75; p = 0.007) compared to delayed initiation.
AKI, acute kidney injury; CI, confidence interval; ICU, intensive care unit; IV, inverse variance; KRT, kidney replacement therapy; MD, mean difference; SD, standard deviation.

CI, 0.05 to 2.01; p = 0.04). Regarding complications, the delayed KRT group experienced fewer catheter-related bloodstream infections (risk ratio [RR], 2.00; 95% CI, 1.21 to 3.29; p = 0.006) and hypophosphatemia (RR, 1.56; 95% CI, 1.03 to 2.36; p = 0.04). There were no differences in hypotension, hypokalemia, hyperkalemia, arrhythmia, hypocalcemia, and bleeding between the 2 groups.

However, caution is needed when interpreting our results, as each RCT has a different research design. Besides the ICU admission which we mentioned previously, definition of AKI, requirement of inotropics or ventilator, the initiation criteria or initiation time for KRT, and included specific population (e.g. sepsis, post-operation, and heart failure) were another important issues.

Since patient characteristics and the definitions of early versus delayed initiation vary substantially across trials, careful interpretation is required. The specifics of each are detailed in the evidence table. Our results did not imply that early initiation of KRT should not be done, rather overly delayed initiation, as seen in the AKIKI 2 trial, may lead to worsened mortality [16]. Therefore, it is crucial to perform KRT at an appropriate time. Further well-designed large RCTs are warranted to establish the optimal timing for initiating KRT.

https://doi.org/10.5049/EBP.2026.24.e1

1.5) Considerations

1.5.1) Benefits and harms

Based on prior research, the timing of KRT initiation does not appear to influence major clinical outcomes, such as mortality. Nonetheless, the optimal timing for initiation may vary depending on the patient's specific conditions; early initiation is preferable in some cases, while in other instances, a delayed start may be more beneficial. It is essential to begin KRT at an appropriate time, tailored to the clinical circumstances of the patient, taking into account the guidelines provided in our recommendations.

1.5.2) Patients' values and preferences

From the patient's perspective, there is no preference for a specific timing between early initiation and delayed initiation. Since the decision regarding when to begin KRT is typically made by attending physicians, discussing patient values and preferences in this guideline holds little significance.

1.5.3) Obstacles and solutions

There are no specific obstacles anticipated in applying this recommendation to clinical practice. However, the timing of applying KRT may vary depending on the opinions of each medical staff member.

1.5.4) Resources

KRT can be performed in all Korean tertiary hospitals. However, there has been no analysis of cost-effectiveness related to KRT timing.

Key Question 2

2.1) PICO question

(P) In patients with AKI starting CKRT, does (I) high dose therapy (> 40 mL/kg/hr) improve (O) outcomes such as survival rate, length of stay, and renal outcomes compared to (C) conventional dose therapy (20–25 mL/kg/hr)?

2.2) Recommendation

We do not recommend high dose (> 40 mL/kg/hr) therapy for patients receiving CKRT for AKI.

2.3) Summary of recommendation statements

1. In patients receiving CKRT for AKI, there is no difference in mortality (28-day mortality, 90-day mortality, and in-hospital mortality) between high-dose therapy and conventional dose therapy.
2. In patients undergoing CKRT for AKI, high dose therapy has no difference in renal prognosis compared to conventional dose therapy.
3. In patients undergoing CKRT for AKI, high dose therapy has been shown to prolong the ICU stay and total hospitalization period compared to conventional dose therapy.

Evidence level: Moderate

Strength of recommendation: C (Against recommendation)

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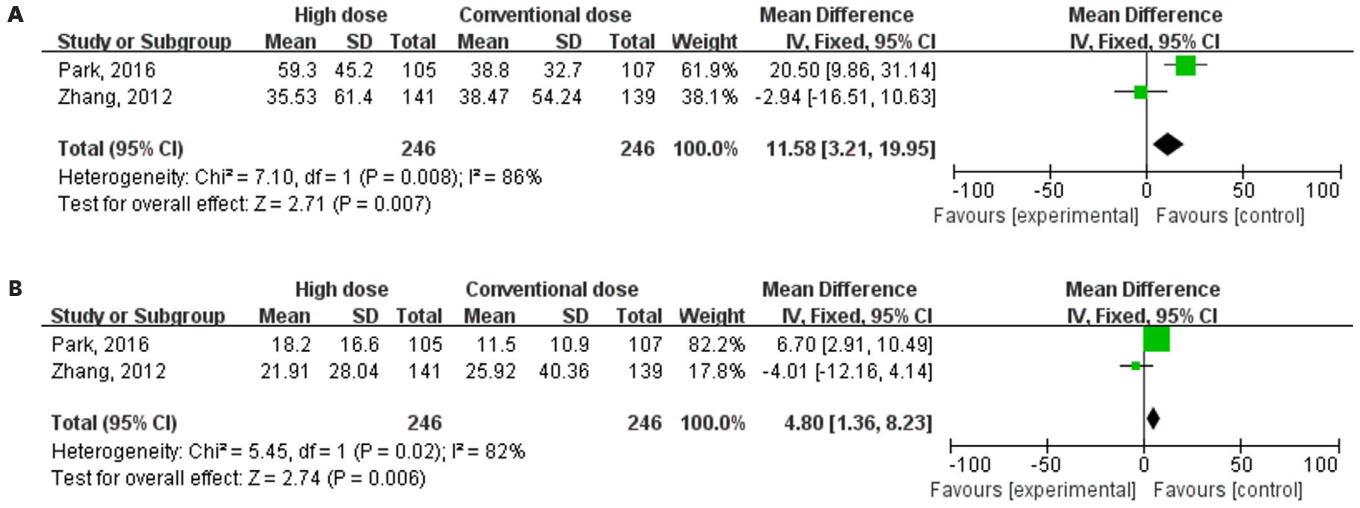

Fig. 2. Length of hospital stay and ICU stay comparing high-dose versus conventional-dose CKRT in adults with AKI (Key Question 2).
Forest plots demonstrating the MDs in (A) total hospital stay and (B) ICU stay between high-dose (> 40 mL/kg/hr) and conventional-dose (20–25 mL/kg/hr) CKRT in adult patients with AKI. Data were pooled using a fixed-effect model. High-dose therapy was associated with a longer duration of hospitalization (MD, +11.58 days; 95% CI, 3.21 to 19.95; p = 0.007) and a longer ICU stay (MD, +4.80 days; 95% CI, 1.36 to 8.23; p = 0.006) when compared to conventional-dose CKRT.
AKI, acute kidney injury; CI, confidence interval; CKRT, continuous kidney replacement therapy; ICU, intensive care unit; IV, inverse variance; KRT, kidney replacement therapy; MD, mean difference; SD, standard deviation.

2.4) Rationale

Determining the appropriate CKRT dose for AKI is essential to ensure effective removal of uremic toxins and correction of electrolyte imbalances and metabolic acidosis. Dose is defined as the total effluent volume (mL/kg/hr) removed from the patient per hour. According to the 2012 KDIGO guidelines, the recommended effluent volume falls within the range of 20–25 mL/kg/hr, as established by the results of 2 randomized trials. This recommendation assigns a grade of 1A [23,24].

Nevertheless, studies have indicated that patients may experience improved prognosis through the effective removal of inflammatory cytokines when undergoing CKRT with a higher dose [25-27]. In this practice guideline, we aim to investigate whether commencing therapy with a higher dose (> 40 mL/kg/hr) for patients undergoing CKRT for AKI yields benefits in terms of survival, length of hospital stay, and kidney outcome compared to cases starting with the conventional dose (20–25 mL/kg/hr). To explore this, we have reviewed four randomized clinical trials published after the 2012 practice guidelines.

Following a meta-analysis of four prospective randomized clinical trials conducted in patients with septic shock, it was observed that CKRT administered at a high dose did not yield a statistically significant improvement in 28-day mortality compared to conventional dose (odds ratio [OR], 0.96; 95% CI, 0.68 to 1.37; p = 0.84) (**Supplementary Fig. 3**, KQ2 A) [28-30]. Likewise, there was no significant difference in the 90-day mortality (OR, 1.03; 95% CI, 0.74 to 1.43; p = 0.87) [28,29,31]. Furthermore, no substantial variance was observed in whether maintenance dialysis was required due to the progression of end-stage renal failure either 90 days after CKRT or at the time of discharge (OR, 0.92; 95% CI, 0.50 to 1.69; p = 0.80) [28-31]. However, it is worth noting that in the high dose group, both the duration of stay in the ICU and the overall hospitalization period were significantly prolonged (ICU stay: MD, 4.8; 95% CI, 1.36 to 8.23; p = 0.006 and hospital stay: MD, 11.58; 95% CI, 3.21 to 19.95; p = 0.007, respectively) (**Fig. 2**) [28,29]. Regarding inflammatory cytokines, one study detected a noteworthy decrease in interleukin (IL)-6, IL-8, IL-1β, and IL-10 levels in the high dialysis

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dose group [29], while another study showed no significant differences in IL-6, IL-8, IL-10, IL-12, tumor necrosis factor-α, and interferon-γ levels [30].

However, when applying pre-dilution, it's important to consider an increase in the prescribed dose. Several studies have highlighted instances where the actual delivered dialysis dose often falls below the prescribed dose due to factors such as discontinuation of CKRT, prior dilution, or reduced membrane permeability during treatment [32,33]. Therefore, in clinical practice, aiming for a dose of 20 to 25 mL/kg/hr, it is typically advisable to prescribe a dialysis dose ranging from 25 to 30 mL/kg/hr. Simultaneously, efforts should be made to minimize disruptions in CKRT.

In addition, in clinical situations where metabolic acidosis, hyperkalemia, or other conditions are not corrected despite CKRT at the conventional dose, a temporary increase in dialysis dose may be considered with a return to the conventional dose once the underlying cause necessitating the higher dose has been resolved.

2.5) Considerations

2.5.1) Benefits and harms

There are reports suggesting that temporarily administering high dose can be beneficial for patients with CKRT experiencing acute septic shock with uncorrected metabolic acidosis and a hypercatabolic state [34]. However, several large-scale RCTs have consistently reported that high-intensity KRT is associated with a significantly increased incidence of electrolyte disturbances, such as hypokalemia and hypophosphatemia [23,24]. In the study by Park et al. [29] reviewed in this guideline, although statistical significance was not reached due to an aggressive electrolyte replacement protocol, a trend toward a higher incidence of hypophosphatemia was observed in the high-dose group (23.3% vs. 15.1%). Similarly, Joannes-Boyau et al. [31] reported a significant increase in the frequency of hypophosphatemia events (88% vs. 38%, $p < 0.01$) and an increased incidence of hypokalemia (30% vs. 20%) in the high-volume group [31]. Furthermore, reports indicate that high-dose therapy significantly affects the clearance of drugs, including antibiotics, thereby adversely affecting patient prognosis [35,36]. Therefore, when treating patients with severe septic shock, the dose of CKRT should be carefully adjusted, considering these risks.

2.5.2) Patients' values and preferences

Patients generally do not have specific values or preferences regarding the decision on dialysis dose when performing CKRT, and treatment selection is generally made based on the medical judgment of the medical staff.

2.5.3) Obstacles and solutions

There are no anticipated obstacles foreseen in the implementation of this recommendation in clinical practice.

2.5.4) Resources

CKRT is available without restrictions in the domestic medical environment.

Key Question 3

3.1) PICO question

(P) In adult patients with AKI requiring RRT, does (I) CKRT improve the outcomes of (O) mortality and length of stay compared to (C) IHD?

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3.2) Recommendation

In patients with AKI, CKRT can be considered a primary modality of RRT along with IHD, and its selective application may be considered in patients with high severity or hemodynamic instability, such as hypotension or arrhythmia.

3.3) Summary of recommendation statements

1. CKRT does not demonstrate a significant difference in mortality compared to IHD.
2. CKRT does not demonstrate a significant difference in the length of ICU stay or total hospitalization duration compared to IHD.
3. CKRT does not demonstrate a significant difference in prognosis compared to prolonged intermittent renal replacement therapy (PIRRT).
4. In patients with relatively higher severity, CKRT tends to be associated with improved prognosis compared to IHD.

Evidence level: Moderate

Strength of recommendation: B (Conditional recommendation)

3.4) Rationale

The appropriate application of RRT in critically ill patients with AKI is clinically important, as it can reduce mortality and complications, thereby improving prognosis [37]. In general, patients with severe AKI often present with hemodynamic instability due to septic shock or other underlying factors, and severe AKI is more prevalent among patients admitted to the ICU [38]. In hemodynamically unstable ICU patients, conventional hemodialysis poses a risk of complications such as hypotension, shock, and arrhythmias [39]. CKRT, with its relatively lower dialysis flow rate, is expected to help maintain hemodynamic stability [40]. However, compared to conventional hemodialysis, CKRT requires more resources and personnel. Therefore, selecting the appropriate type of RRT for AKI patients and initiating CKRT in optimal candidates is essential for efficient workforce management and resource allocation. Numerous studies have been conducted to examine whether different RRT modalities impact the prognosis of AKI patients. In this clinical practice guideline, we reviewed and conducted a meta-analysis of 12 prospective RCTs that compared the clinical outcomes of CKRT with those of intermittent renal replacement therapies [41-52]. Among the 12 studies, seven used conventional IHD as the control group, while the remaining 5 adopted PIRRT as the comparator.

Compared with IHD, CKRT did not demonstrate a statistically significant improvement in in-hospital mortality (RR, 1.00; 95% CI, 0.93 to 1.09). Likewise, there was no difference in mortality between CKRT and PIRRT (RR, 1.20; 95% CI, 0.96 to 1.50). Hazard ratios for ICU mortality were available from 5 studies, yet no significant differences were observed. In addition, 6 studies compared total hospital length of stay and ICU length of stay, but neither outcome showed a statistically significant difference between treatment groups. When the control group was stratified into conventional IHD and PIRRT, there remained no significant differences between CKRT and either control modality across ICU mortality, total hospital stay, or ICU length of stay (**Fig. 3**) [41-52].

Evidence remains insufficient to confirm that CKRT improves prognosis and reduces complications in hemodynamically unstable patients compared to IHD. Among the

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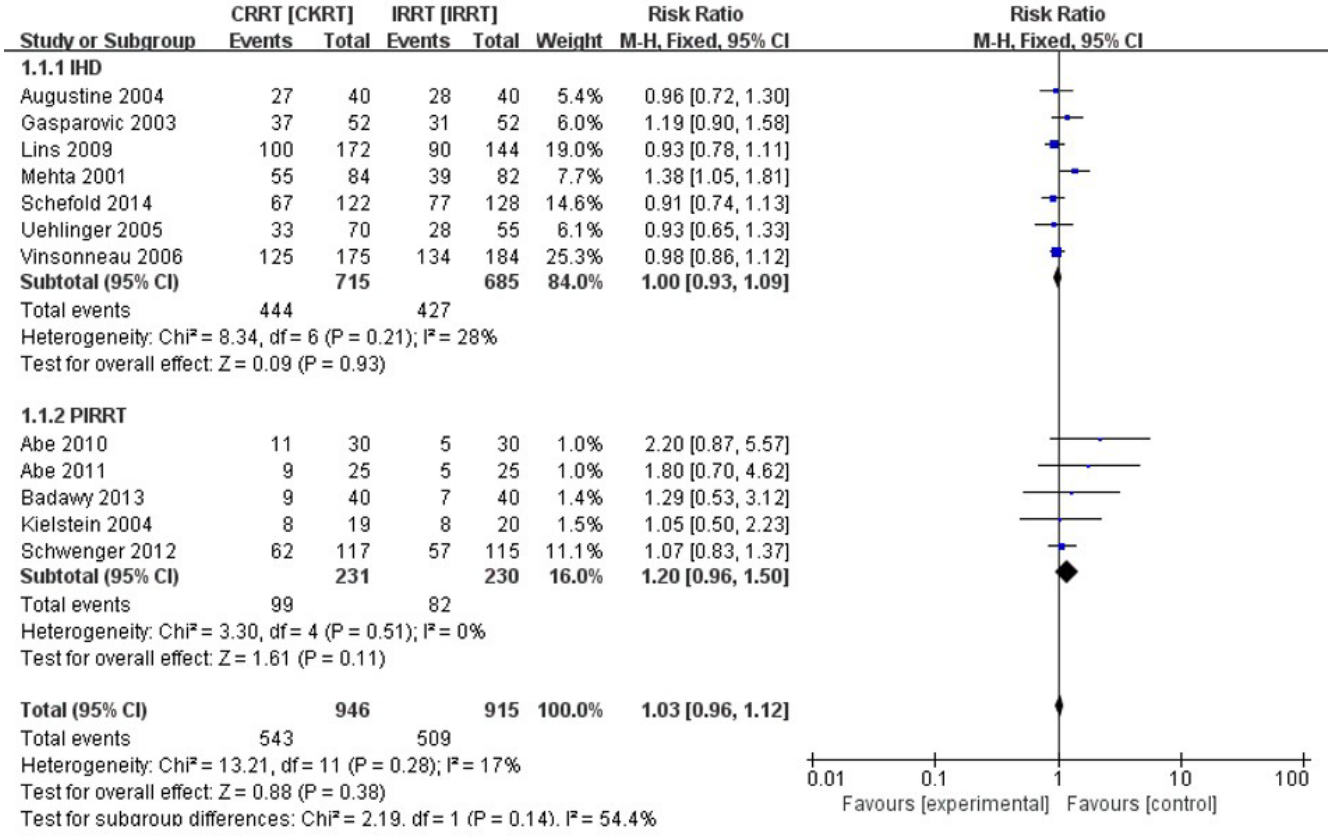

Fig. 3. Overall mortality comparing continuous versus intermittent KRT in adults with AKI (Key Question 3).
Forest plot of RCTs comparing overall mortality between CKRT and IRRT, including IHD and PIRRT, in adult patients with AKI. Pooled effect estimates were calculated using a fixed-effect model. No statistically significant difference in mortality was observed between CKRT and IRRT (RR, 1.03; 95% CI, 0.96 to 1.12; p = 0.38). Subgroup analysis also demonstrated no significant mortality difference between CKRT and IHD or PIRRT.
AKI, acute kidney injury; CI, confidence interval; CKRT, continuous kidney replacement therapy; IHD, intermittent hemodialysis; IRRT, intermittent renal replacement therapy; KRT, kidney replacement therapy; M-H, Mantel-Haenszel; PIRRT, prolonged intermittent renal replacement therapy; RCT, randomized controlled trial; RR, risk ratio.

12 RCTs included in the meta-analysis, 4 studies provided subgroup analyses comparing CKRT with intermittent dialysis specifically in patients with hemodynamic instability; however, none demonstrated a significant difference in clinical outcomes between the treatment modalities [44,47,49,51]. In contrast, 2 studies reported that 7.6–19.5% of patients initially assigned to IHD required conversion to CKRT due to hemodynamic instability [47,49]. These findings suggest that while routine use of CKRT solely for prognostic benefit may not be warranted, CKRT may be considered in patients with AKI who require KRT who cannot tolerate IHD due to hemodynamic instability. According to a follow-up analysis of the AKIKI and IDEAL-ICU study results in 2022 [53], IHD demonstrated superior survival outcomes in patients with mild AKI and lower Sequential Organ Failure Assessment (SOFA) scores. However, in patients with moderate to severe AKI and higher SOFA scores, there was no significant difference in survival prognosis between treatment modalities, and the CKRT group even showed a trend toward better survival. These findings indirectly suggest that IHD may be preferred for patients with mild AKI, whereas CKRT may be a more suitable option for critically ill patients with hemodynamic instability.

To date, no Korean prospective randomized clinical trials have examined the effectiveness of CKRT in adult AKI patients with hemodynamic instability, and further clinical evidence is needed.

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3.5) Considerations

3.5.1) Benefits and harms

In adult patients with AKI, CKRT does not demonstrate a significant difference in prognosis compared to IHD in terms of in-hospital mortality, ICU mortality, or hospital length of stay. Evidence remains insufficient regarding whether CKRT increases the risk of infections or dialysis access dysfunction compared to IHD.

3.5.2) Patients' values and preferences

In general, conscious patients with AKI may be relatively hesitant to undergo CKRT, as it requires continuous treatment up to 24 hours. However, patients with impaired consciousness due to the use of sedative drugs or other comorbid conditions are less likely to have a preference between CKRT and IHD. Patients who repeatedly experience treatment-related complications such as shock, arrhythmias, or seizures during hemodialysis may prefer CKRT.

3.5.3) Obstacles and solutions

CKRT is generally preferred for hemodynamically unstable adult critically ill patients. However, in routine clinical settings, there is often a shortage of specialized personnel and equipment required to perform CKRT. If the guideline facilitates the efficient use of various RRT modalities and reduces the duration of CKRT, it may help overcome barriers such as shortages of trained personnel and limitations in facility capacity.

3.5.4) Resources

In some healthcare institutions, where medical resources such as personnel and dialysis machines for performing IHD in the ICU are limited, CKRT may be preferred.

Key Question 4

4.1) PICO question

(P) In patients with CKRT, (I) does the combined use of phosphate-containing dialysate decrease the frequency of hypophosphatemia, improve (O) patient survival, reduce cardiac arrhythmias, decrease the duration of mechanical ventilation, and decrease the length of stay in the ICU or hospital (C) compared to the use of non-phosphate-containing dialysate only?

4.2) Recommendation

The use of phosphate-containing dialysate may be considered to prevent hypophosphatemia in patients on CKRT.

4.3) Summary of recommendation statements

1. In patients on CKRT, the use of phosphate-containing dialysate is associated with a lower frequency of hypophosphatemia and higher blood phosphate concentration compared to the use of non-phosphate-containing dialysate alone.
2. In patients on CKRT, the use of phosphate-containing dialysate may be associated with shorter duration of mechanical ventilation and ICU and hospital length of stay compared with the use of dialysate without phosphorus alone, but evidence is lacking.
3. There is no evidence that the use of phosphate-containing dialysate improves survival compared to the use of dialysate without phosphorus alone in patients on CKRT.
4. There is no available study comparing the efficacy of dialysate with directly mixed phosphate versus commercially available phosphate-containing dialysate. Therefore, there is insufficient evidence to recommend a specific method.

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Evidence level: Very low

Strength of recommendation: B (Conditional recommendation)

4.4) Rationale

Hypophosphatemia is common in patients on CKRT. Hypophosphatemia can cause a decrease in muscle contractility and affect the affinity of oxygen to hemoglobin, which in turn can reduce the patient's cardiorespiratory capacity and hinder rehabilitation. Severe hypophosphatemia can also cause rhabdomyolysis. Previously, preventing or treating hypophosphatemia in patients on CKRT required intravenous or enteral supplementation. Recently, however, phosphate-containing dialysate has been introduced into CKRT to prevent or treat hypophosphatemia. This guideline examines the effect of using phosphate-containing dialysate, compared with non–phosphate-containing dialysate, on hypophosphatemia, arrhythmic events, duration of mechanical ventilation, ICU and hospital length of stay, and mortality in patients receiving CKRT.

There is no RCT comparing the effects of phosphate-containing dialysate versus phosphate-free dialysate in patients undergoing CKRT. In several observational cohort studies, the use of phosphate-containing dialysate was associated with a lower incidence of hypophosphatemia compared to the use of non-phosphate-containing dialysate [54-63]. However, different studies used different criteria for the frequency of hypophosphatemia and different study designs, making comparisons difficult. Thompson Bastin et al. [54] and Broman et al. [55] reported outcomes as the number of patients with hypophosphatemia in total patients, Godaly et al. [56] and Crowly et al. [57] reported outcomes as the number of treatment days with hypophosphatemia in total cumulative treatment days, and Morabito et al. [59] reported outcomes as the frequency of hypophosphatemia in total blood phosphate measurements. Cho et al. [58] presented only incidence rate ratios and did not report each frequency or incidence. Nalesso et al. [60] and Chua et al. [62] reported only blood phosphate concentrations, not frequency of hypophosphatemia. In terms of study design, another study of Chua et al. [61] compared serum phosphate concentration in patients who received sequentially non-phosphate-containing and phosphate-containing dialysate. Song et al. [63] used dialysate phosphate concentrations of 2.0 or 3.0 mmol/L, which is much higher than the 1.2 mmol/L used in other studies. One prospective study by Besnard et al. [64] used a crossover design to study the effect of phosphate-containing dialysate and found that phosphate-containing dialysate was associated with higher phosphate concentrations and less frequent phosphate supplementation. Despite the differences between these studies, all studies, including Thompson Bastin et al. [54], which included 1,396 patients, and Cho et al. [58], which included 324 patients, consistently reported a decreased frequency of hypophosphatemia or a higher phosphate concentration when using phosphate-containing dialysate. On the other hand, hyperphosphatemia tended to increase in the group using phosphate-containing dialysate.

Thompson Bastin et al. [65] reported a shorter duration of mechanical ventilation with the use of phosphate-containing dialysate compared with the use of non-phosphate-containing dialysate in patients on CKRT but Crowley et al. [57] reported no difference. Other studies did not report on duration of mechanical ventilation. The study of Thompson Bastin et al. [65] was relatively large, including 992 patients, whereas the study of Crowley et al. [57] included only 60 patients. Thus, there is a possibility that the use of phosphate-containing

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dialysate may reduce the duration of mechanical ventilation, but the evidence is still weak. Similar to the results for the duration of mechanical ventilation, only Thompson Bastin et al. [54] and Crowley et al. [57] reported ICU length of stay or hospital length of stay, with Thompson Bastin et al. [54] reporting shorter ICU length of stay or hospital length of stay with the use of phosphate-containing dialysate compared with the use of non-phosphate-containing dialysate and Crowley et al. [57] reporting no difference. As for mortality, Thompson Bastin et al. [54] and Crowley et al. [57] reported in-hospital mortality, while Cho et al. [58] reported 30-day mortality with no difference based on phosphate-containing dialysate use. No studies reported cardiac arrhythmias.

Baeg et al. [66] suggested that the use of phosphate-containing dialysate according to a pre-defined CKRT fluid protocol based on blood phosphate level may reduce the variability of blood phosphate concentrations and reduce the frequency of abnormal blood phosphate concentrations compared to no protocol, but they did not directly evaluate the effect of phosphate-containing dialysate compared with non-phosphate-containing dialysate. Cho et al. [58] used in a predefined CKRT fluid protocol based on blood phosphate concentration. Therefore, it may be useful to use phosphate-containing dialysate according to a pre-defined CKRT fluid protocol based on blood phosphate levels, but the evidence is still lacking.

The studies by Thompson et al. [54,65] did not specify how the phosphate-containing dialysate was prepared. Song et al. [63] reported that phosphate was directly mixed into the dialysate, whereas the other referenced studies compared the effects of commercially available phosphate-containing dialysate versus phosphate-free dialysate. However, since no study has directly compared dialysate with manually mixed phosphate versus commercially available phosphate-containing dialysate, there is insufficient evidence to recommend a specific method. In patients on CKRT, the use of phosphate-containing dialysate may help prevent hypophosphatemia.

One study reported that the use of phosphate-containing dialysate was associated with a reduction in duration of mechanical ventilation, ICU, and hospital length of stay compared with non- phosphate-containing dialysate, but the evidence is still lacking, and mortality does not appear to be affected by phosphate-containing dialysate. Given that no significant increase in complications has been reported with the use of phosphate-containing dialysate and the potential complications of hypophosphatemia, the use of phosphate-containing dialysate may be recommended in patients on CKRT.

4.5) Considerations

4.5.1) Benefits and harms

In patients on CKRT, the use of phosphate-containing dialysate may prevent hypophosphatemia. There are also potential benefits in terms of shorter duration of mechanical ventilation and shorter ICU and hospital length of stay in mechanically ventilated patients. On the other hand, using phosphate-containing dialysate carries the risk of hyperphosphatemia. Therefore, phosphate-containing dialysate should be used cautiously in patients with pre-existing or persistent hyperphosphatemia.

4.5.2) Patients' values and preferences

Most patients on CKRT are critically ill in the ICU and do not have a preference for using a specific dialysate. Therefore, the choice of dialysate is usually based on the medical judgment of the healthcare provider.

4.5.3) Obstacles and solutions

The use of phosphate-containing dialysate indicates that at least 2 or 3 types of dialysates should be adequately stocked and available, compared to the use of 1 or 2 type of non-phosphate-containing dialysates. To prevent hyperphosphatemia, it is necessary to actively exchange dialysate according to the blood phosphate concentration. Therefore, proper protocols and training of medical staff (doctors, nurses) are required for each institution. However, using a predefined protocol based on blood phosphate concentrations can help avoid dosing errors and increasing workload [66].

There is no evidence to suggest a difference in efficacy between dialysate with manually mixed phosphate and commercially available phosphate-containing dialysate. However, manually mixing phosphate into the dialysate may increase the workload for healthcare providers and pose risks of incomplete mixing, potentially exposing patients to transiently high concentrations of phosphate or potassium. Therefore, for convenience and safety, the use of commercially available phosphate-containing dialysate may be considered.

4.5.4) Resources

The use of phosphate-containing dialysate may result in significant cost savings due to shorter duration of mechanical ventilation and ICU or hospital stays, but evidence is lacking. Since commercially available phosphate-containing dialysate is more expensive than phosphate-free dialysate, if cost is a concern, an alternative approach may be to manually mix potassium phosphate ampoules into the CKRT dialysate.

Key Question 5

5.1) PICO question

(P) In patients receiving CKRT, does (I) early intensified net negative ultrafiltration or early negative fluid balance reduce (O) mortality, KRT dependency, or length of ICU stay compared to (C) non-intensified ultrafiltration?

5.2) Recommendation

Non-intensified net ultrafiltration rate to achieve net negative fluid balance may be utilized to avoid positive cumulative fluid balance in critically ill patients with volume overload during the early period after the CKRT initiation. We suggest using individualized net ultrafiltration rate based on patients' volume status and ability to tolerate fluid removal.

5.3) Summary of recommendation statements

1. Positive fluid balance during the early period after CKRT initiation was associated with increased mortality.
2. Studies designed to examine the association between early (48–72 hours) intensified net ultrafiltration and mortality in patients with fluid overload showed mixed results.

Strength of recommendation: Expert consensus

5.4) Rationale

It is well known that fluid overload can result in reduced organ perfusion, multiorgan dysfunction, and increased mortality [67]. There has been increasing recognition of the deleterious consequence of positive fluid balance in critical care [68]. Thus, fluid removal

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with net negative ultrafiltration is likely to have an important role in critically ill patients under CKRT [69]. However, a faster net ultrafiltration rate can potentially lead to ischemic organ injury and cardiac stress [69]. It is desirable if the net ultrafiltration rate is applied with the rate of treating fluid overload effectively and avoiding deleterious consequences of ultrafiltration-derived hemodynamic stress. However, there has been no consensus regarding the adequate net ultrafiltration rate in critically ill patients under CKRT.

There are no prospective intervention studies comparing the rate of net ultrafiltration. Although modern RCTs designed to evaluate the timing of KRT initiation were recently published, none of these trials addressed volume status and examined the ultrafiltration rate [13,14,17]. Therefore, the rationale of this recommendation is limited to retrospective observational studies. An earlier large study that sophisticatedly addressed the different ranges of hourly net ultrafiltration rate demonstrated that an intensified net ultrafiltration rate (ultrafiltration rate greater than 1.75 mL/kg/hr) was associated with increased risk of mortality compared to slower net ultrafiltration rates [70]. This finding was reproduced by the later study designed to examine the early period (first 48 hours) after CKRT initiation [71,72]. Moreover, the intensified net ultrafiltration was associated with a higher risk of KRT dependency and longer length of ICU stay [73]. We, therefore, suggest avoiding intensified ultrafiltration rate greater than 1.75 mL/kg/hr unless there is an individualized clinical indication that requires rapid volume removal until the safety is confirmed by future trials. However, it is important to note that this does not mean that net negative fluid balance should be avoided during the early period of CKRT. Observational studies that addressed early fluid balance after CKRT initiation consistently showed that the positive fluid balance was associated with increased mortality [74-77]. Moreover, in patients with fluid overload status, a lower risk of mortality was observed in patients with a daily negative fluid balance greater than 25 mL/kg/day compared to those with lower daily negative fluid balance (≤ 20 mL/kg/day) [75]. When the analysis was limited to the fluid balance during the first 72 hours after CKRT initiation, this association was consistently observed [75]. The hypothetical J-shape association between net negative ultrafiltration rate and mortality has been suggested [69,70]. Therefore, the application of modest net negative ultrafiltration in clinically indicated patients or in those with volume overload is likely acceptable based on the data from the observational studies. However, the safe threshold or recommended net ultrafiltration rate cannot be suggested with the currently available evidence.

Given that the rationale is limited to several retrospective observational studies with a high risk of bias, we limit the recommendation level to the expert consensus. Future randomized trials designed to investigate the clinical effect of different net ultrafiltration rates are warranted.

5.5) Considerations

5.5.1) Benefits and harms

The early intensified net negative ultrafiltration rate was associated with a higher risk of mortality. Non-intensified net negative ultrafiltration to avoid positive fluid balance was associated with a lower risk of mortality.

5.5.2) Patients' values and preferences

There is unlikely to be a patient preference issue regarding CKRT net ultrafiltration.

5.5.3) Obstacles and solutions

Hypotension and hemodynamic instability can occur during ultrafiltration. Fluid removal

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can be temporarily withheld, and an effort to find and correct the underlying cause of hypotension is required. The input volume and urine output should be considered for the net ultrafiltration prescription. A strategy minimizing or reducing infused volume can be used in order to achieve net negative fluid balance and avoid intensified net ultrafiltration. A recent multicenter randomized clinical trial investigated the use of bioelectrical impedance analysis (BIA)-guided ultrafiltration adjustment to maintain appropriate fluid balance in patients with AKI undergoing CKRT. While long-term survival rates showed no significant difference, BIA-guided ultrafiltration control was associated with a reduction in 28-day mortality and improved fluid balance on day 1. Clinically, BIA may serve as a useful tool for individualized ultrafiltration rate adjustment in patients receiving CKRT [78].

5.5.4) Resources

There is no resource issue with modifying the net ultrafiltration rate using CKRT.

Key Question 6

6.1) PICO question

(P) In patients with ADHF, does (I) ultrafiltration therapy compared to (C) pharmacological treatment result in (O) better fluid removal or weight loss, changes in kidney function, and reduction in heart-failure rehospitalization rates and mortality?

6.2) Recommendation

Ultrafiltration therapy should be carefully considered in selected patients with ADHF who exhibit diuretic resistance.

6.3) Summary of recommendation statements

In patients with ADHF,

1. Ultrafiltration therapy may be more effective in fluid removal compared to pharmacological treatment.
2. Ultrafiltration therapy may be more effective in weight loss compared to pharmacological treatment.
3. There is no significant difference in renal function between ultrafiltration therapy and pharmacological treatment.
4. Ultrafiltration therapy may lead to complications such as bleeding, catheter-related infections, and hemodynamic instability.
5. Ultrafiltration therapy significantly reduces the rate of rehospitalization for heart failure compared to pharmacological treatment.
6. Ultrafiltration therapy has a similar effect on mortality compared to pharmacological treatment.

Evidence level: Moderate

Grade: I (Inconclusive)

6.4) Rationale

In patients with ADHF, fluid overload is a common and predominant symptom requiring hospitalization. Therefore, effective fluid management in acute heart failure patients is

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crucial for symptom improvement and better prognosis. While diuretics are predominantly used for fluid management in acute heart failure, they are often ineffective due to frequently accompanied AKI. Ultrafiltration is known as an effective treatment for decongestion that does not respond well to diuretics in patients with ADHF. Several previous RCTs have demonstrated the superiority of ultrafiltration therapy over pharmacological treatment in terms of fluid management and readmission rates [79-83]. However, there is caution in the application of ultrafiltration therapy, as it may have treatment-associated adverse events such as worsening of kidney function, catheter-related infections, anemia, bleeding, and hemodynamic instability [80,84,85]. Furthermore, there are currently no clinical guidelines providing recommendations for the use of ultrafiltration therapy in ADHF patients, and therefore selecting between ultrafiltration and pharmacological treatment remains challenging. According to the 2021 European Society of Cardiology Guidelines for the diagnosis and treatment of acute and chronic heart failure, in patients with heart failure who do not respond to diuretics, ultrafiltration can be considered; however, the guidelines indicate a lack of evidence regarding the effects on patient's outcome of ultrafiltration therapy [81,84,86]. In the 2022 American Heart Association Guideline for the management of heart failure, it is reported that early implementation of ultrafiltration therapy in heart failure patients, when compared to diuretics in some studies, is effective in fluid removal and reduces readmission rates [81,87,88]. However, the guideline also points out potential complications such as catheter-related complications associated with the implementation of ultrafiltration therapy [84]. Therefore, the guidelines emphasize the need for future comprehensive research on the effect of ultrafiltration therapy in heart failure patients to appropriately select patients and fluid removal rates, and minimize treatment-related side effects and costs.

In this clinical guideline, we reviewed 7 RCTs to assess the effects of ultrafiltration therapy in patients with ADHF on symptom improvement, renal function, heart-failure rehospitalization, and mortality, compared with pharmacological treatment.

In RCTs, ultrafiltration therapy showed a significant effect in fluid removal compared to pharmacological treatment after 48 hours of treatment initiation (**Supplementary Fig. 3**, KQ6) [80,81,83]. Additionally, in terms of weight loss at 48 and 72 hours after treatment initiation, ultrafiltration therapy demonstrated a significantly superior effect over pharmacological treatment [79,81,83,89]. When comparing changes in kidney function as measured by changes in serum creatinine concentration, there was no significant difference between ultrafiltration therapy and pharmacological treatment at 48 hours after treatment initiation [83,87,90]. Regarding rehospitalization rate for heart failure at 90 days after treatment initiation, ultrafiltration therapy significantly reduced the rate compared to pharmacological treatment [81,87,89,90]. However, there was no significant difference in mortality at 90 days after treatment initiation between ultrafiltration therapy and pharmacological treatment [87,89,90].

In conclusion, ultrafiltration therapy can be considered for patients with ADHF as it effectively removes fluid, reduces body weight, and lowers the rate of heart failure-related rehospitalization compared to pharmacological treatment. However, because no mortality benefit has been demonstrated, its use should be carefully individualized based on clinical context.

6.5) Considerations

6.5.1) Benefits and harms

In patients with ADHF, ultrafiltration therapy is effective when compared to pharmacological

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treatments including diuretics, for alleviating fluid overload, and there is no significant differences in adverse effects, such as worsening of kidney function. In particular, compared to pharmacological treatment, ultrafiltration therapy significantly reduces the rehospitalization rates for heart failure in patients with ADHF, providing therapeutic benefits. However, caution is needed that catheter insertion is necessary for ultrafiltration therapy and potential risks such as catheter-related infection and bleeding need to be considered.

6.5.2) Patients' values and preferences

From the patient's perspective, there may be reluctance to undergo invasive procedures such as catheter insertion for the administration of ultrafiltration therapy, and there may be concerns about hemodynamic instability, such as hypotension during the treatment period. However, it is essential to provide education to patients so that they are well-informed about the potential benefits of ultrafiltration therapy by effectively improving symptoms from fluid overload and reducing readmissions compared to pharmacological treatment. This awareness will enable patients to make informed decisions regarding their treatment.

6.5.3) Obstacles and solutions

While the invasive procedures, such as catheter insertion, and the potential need for admission to an ICU for ultrafiltration therapy, can be barriers, it is essential to explain to patients the potential benefits of ultrafiltration therapy effectively improving symptoms from fluid overload and significantly reducing readmission rates compared to pharmacological treatment. Overcoming these obstacles by providing a clear understanding of the potential advantages of ultrafiltration therapy is crucial.

6.5.4) Resources

The utilization of equipment for ultrafiltration, catheter insertion, and securing an ICU may require resources, but ultimately, it can lead to resource savings compared to pharmacological treatment by rapidly alleviating symptoms in heart failure patients and reducing readmission rates.

Key Question 7

7.1) PICO question

(P) In adult patients with AKI undergoing CKRT, does (I) the use of diuretics at the time of discontinuing therapy, compared with (C) not using diuretics, improve (O) outcomes such as increased urine output, duration of CKRT, length of hospital stay, or mortality?

7.2) Recommendation

In adult patients undergoing CKRT for AKI, the use of diuretics may be considered at the time of CKRT discontinuation to facilitate urine output recovery.

7.3) Summary of recommendation statements

1. In adult patients undergoing CKRT for AKI, existing studies on diuretic use are heterogeneous with respect to patient selection, dosing strategies, and routes of administration; however, diuretic therapy has generally been associated with increased urine output.
2. However, diuretic use has not been associated with improved renal recovery or a reduction in AKI duration. Additionally, it has shown no significant impact on ICU length of stay or mortality rates.

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3. While the increase in urine output induced by diuretics may be associated with earlier CKRT discontinuation and a shorter duration of RRT, conflicting study results exist, and these findings should be interpreted with caution.

Evidence level: Low

Strength of recommendation: B (Conditional recommendation)

7.4) Rationale

There are limited existing studies that directly compare the effect of diuretic use on the discontinuation of ongoing KRT in adult patients undergoing CKRT due to AKI. Most studies have explored significant factors associated with discontinuing CKRT and have observed that urine output before and after discontinuation was a significant factor. In many cases, the use of diuretics was investigated during this period. Some studies included diuretic use as an intervention and performed comparisons.

In a single-center study involving patients undergoing CKRT, a RCT was conducted to investigate kidney function recovery based on diuretics [91]. After discontinuing CKRT, urine was collected over 4 hours to measure creatinine clearance. Subsequently, a comparison was made between a randomly assigned group receiving furosemide and a placebo group. Out of 71 patients, 36 were in the furosemide treatment group. Although there was a significant increase in urine output in the diuretic-treated group, diuretic use did not contribute to a reduction in the duration of kidney dysfunction or kidney function recovery. Furthermore, there were no differences in the duration of stay in the ICU and the in-hospital mortality rate between the two groups. In a retrospective cohort study of 1,176 patients with AKI undergoing CKRT, regardless of whether treatment was discontinued, switched to IHD, or resumed CKRT, all groups exhibited increased urine output in the diuretic use subgroup [92]. When examined within the group in which CKRT was discontinued, diuretics led to increased urine output. Moreover, when diuretics were administered through continuous infusion, urine output exhibited an even more pronounced increase. The use of diuretics was shown as a predictive factor for the discontinuation of CKRT. However, within the group using diuretics, kidney function recovery was not observed, and although the difference was not statistically significant, there was a slight increase in serum creatinine levels. Additionally, a direct comparison was not conducted based on diuretic use as an intervention. Thus, the duration of CKRT treatment based on diuretic use was not compared. In several observational studies, increased urine output upon discontinuing CKRT was shown to be a significant factor. While some studies suggested that diuretic use heightened this association [93], there are also studies indicating an inverse relationship between diuretic use and the predictive power for discontinuing CKRT [94]. In a retrospective observational study involving 1,158 patients, the proportion of patients using diuretics the day before discontinuation was higher when CKRT was discontinued. The use of diuretics one day before discontinuation was shown to be a significant factor for stopping CKRT in univariate analysis [95]. However, in multivariable adjustments, the use of diuretics was not statistically significant, whereas urine output remained a significant factor for discontinuing KRT. A small pilot study involving 30 patients compared clinician judgments or protocols based (bolus infusion of furosemide) for discontinuing KRT [96]. There was a higher urine output in the protocol group, although there was no statistically significant difference in diuretic use between the 2 groups. The authors postulated that the increased urine output in the protocol group might be attributed to fluid administration to prevent hypotension and hypovolemia rather than diuretic use. In addition,

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several observational studies comparing successful discontinuation and failure groups of CKRT have consistently shown that the successful group exhibited higher urine output. However, there were no differences between the 2 groups regarding diuretic use rates or quantities [97-100].

Although criteria for diuretic administration at the time of CKRT discontinuation vary across studies, diuretics may generally be considered in patients who are hemodynamically stable and show an increasing trend in urine output. Previous studies have reported that a daily urine output of 125 mL serves as a cutoff value for predicting successful CKRT discontinuation when diuretics are used in oliguric patients attempting CKRT withdrawal [92].

The single RCT providing evidence had a limited sample size, and the processes of randomization and allocation concealment were unclear. In addition, among the nine observational studies, some demonstrated risks of bias as well as inconsistency and imprecision, leading to an overall 'low level of evidence.' Nevertheless, several studies identified increased urine output as an important predictor of successful treatment discontinuation, suggesting potential clinical relevance. Accordingly, although a survival benefit remains uncertain, a 'conditional recommendation' was made to selectively allow diuretic use based on individual patient status for the purpose of fluid management. Currently, in adult patients undergoing CKRT due to AKI, diuretics when CKRT is discontinued have been associated with increased urine output in some studies. However, a lack of research demonstrates improvements in outcomes such as shortened duration of CKRT, kidney function recovery, or mortality. In addition, few studies have intervened on whether or not to use diuretics, therefore more research is needed.

7.5) Considerations

7.5.1) Benefits and harms

While diuretics can lead to increased urine output and facilitate fluid management, potentially allowing for discontinuation of CKRT, it is essential to adjust their administration based on the patient's condition to mitigate risks such as fluid depletion and hypotension.

7.5.2) Patients' values and preferences

If diuretics help stabilize the patient's clinical condition, the use of diuretic therapy may be considered as a treatment option. However, if the patient requires KRT, it would be necessary to discuss the treatment process with the patient and consider their values and preferences. In such cases, it is important to provide the patient with a clear understanding of the treatment options and tailor the approach based on their individual needs and choices.

7.5.3) Obstacles and solutions

As the benefits of using diuretics alone for kidney function recovery or discontinuing CKRT remain unclear in patients undergoing CKRT due to AKI, further research is necessary.

7.5.4) Resources

Given that the advantages of diuretics in patients undergoing CKRT are not prominent, it would be important to allocate resources appropriately and tailor treatment based on the patient's condition.

Key Question 8

8.1) PICO question

(P) In patients with increased bleeding risk, (I) does the use of NM, (C) compared to no anticoagulation, (O) have a clinically beneficial effect?

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8.2) Recommendation

In CKRT patients with a high risk of bleeding who are not receiving systemic anticoagulation and for whom regional citrate anticoagulation is not feasible, anticoagulation with NM may be considered.

8.3) Summary of recommendation statements

1. For CKRT anticoagulation in patients with increased bleeding risk who are not receiving anticoagulation, NM anticoagulation prolongs filter life compared to no anticoagulation.
2. There is little evidence that NM increases bleeding complications compared with no anticoagulation.

Evidence level: Moderate

Strength of recommendation: B (Conditional recommendation)

8.4) Rationale

Regional citrate anticoagulation is the KDIGO-suggested method for anticoagulation during CKRT in patients with increased bleeding risk [101]. However, citrate anticoagulation is currently unavailable in South Korea. No anticoagulation is the next option in this case [101], while increased risk of filter clotting is issued.

We suggest systemic NM anticoagulation rather than no anticoagulation during CKRT in patients with increased bleeding risk. NM is a synthetic serine protease inhibitor with anti-thrombin effect, and its short half-life (6–8 minutes) allows rapid reversal of its systemic anticoagulation effect [102].

Three randomized trials have compared NM to no anticoagulation during CKRT in patients with increased risk of bleeding. The first trial by Park et al. [103] used single-center unblinded design in 43 patients with high risk of bleeding defined by: 1) international normalized ratio > 2, activated partial thromboplastin time > 20 seconds, platelet count < 50,000/mm^3 or 2) ongoing bleeding, major hemorrhage/surgery in the last 48 hours. Twenty patients were treated with continuous NM infusion (10–20 mg/hr) and the remaining 23 patients were treated with saline bolus infusion (100 mL every 1 hour) for continuous veno-venous hemofiltration anticoagulation. Mean filter life was longer in NM infusion group (28.73 ± 12.67 vs. 16.34 ± 7.86 hours, p = 0.001) and there were no significant bleeding complications in either saline bolus or NM infusion group [103].

The second trial was an un-blinded, single center, randomized prospective controlled study based on the 73 CKRT patients with a hemorrhagic tendency. The definition for hemorrhagic tendency was similar to those of Park et al. [103] except for additionally including septic shock or disseminated intravascular coagulation. The initial dose of nafamostat was 20 mg/hr and it was adjusted from 10–30 mg/hr according to each patient's status. The overall number of filters used during CKRT (2.71 ± 2.12 vs. 4.50 ± 3.25, p = 0.042) and the number of filters changed due to clots within 24 hours (1.15 ± 0.81 vs. 1.74 ± 1.62, p = 0.040) were significantly fewer in NM group. There was no significant difference in transfusion rate or survival between the two groups. No adverse event related to NM was noted [104].

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The third trial randomized 55 patients on CKRT with increased risk of bleeding. Allocation to NM or no anticoagulation was un-blinded to the investigators, and definitions for bleeding tendency was similar to the previous 2 studies. Initial dose of NM was 20 mg/hr, then regulated to 10 to 30 mg/hr according to the physicians' decision. Thirty-one patients received NM, and the other 24 received no anticoagulation. The mean filter lifespan was significantly longer in the NM group than in the no anticoagulation group (31.7± 24.1 vs. 19.5 ± 14.9 hours, p = 0.035). There were no significant differences in the frequencies of transfusions and major bleeding between the groups. Patient survival rates at 30 and 90 days after CKRT initiation were comparable between the groups [105].

A recent meta-analysis based on these 3 RCTs reported significantly decreased filter life in no anticoagulation compared to NM group (pooled difference in mean, –10.59; 95% CI, –15.45 to –5.72; Z = 4.26; p < 0.0001). It also reported no differences in the incidence of bleeding complications between the 2 groups (RR, 0.97; 95% CI, 0.36 to 2.44; p = 0.95) without inter-trial heterogeneity (I^2 = 0%; p = 0.65) [106].

Two retrospective observational studies also compared NM and no anticoagulation among the patients on CKRT with bleeding tendency [107,108] and we performed meta-analysis to obtain further rationale (87 with NM, 193 with no anticoagulation). Filter life was longer in NM group than in the no-anticoagulation group by 8.53 hours (95% CI, 3.26 to 13.81; p = 0.002), and the incidence of bleeding complication did not differ between the NM and no anticoagulation group (**Supplementary Fig. 3**, KQ8). Bleeding complications were defined as: visible bleeding with a decrease in blood pressure, transfusion requirement, or a hemoglobin drop of more than 2 g/dL within 24 hours [108].

Hematologic complication (agranulocytosis) or allergic reaction to NM was not reported in these 3 RCTs and 2 observation studies. In the retrospective study by Kim et al. [109], that analyzed the safety of NM anticoagulation for CKRT, the incidence of agranulocytosis was not increased and the hyperkalemia correction rate was not prolonged compared to the no anticoagulation group.

8.5) Considerations

8.5.1) Benefits and harms

For patients with increased bleeding risk and unable to access regional citrate anticoagulation, compared to no anticoagulation, the use of NM is associated with a longer filter life without increased risk of bleeding complications. Agranulocytosis, hyperkalemia, or allergic reactions, the previously issued adverse effects with NM, have not been reported in RCTs or observational studies reviewed, therefore additional data is needed to assess potential risks. Nevertheless, based on the given evidence described above and the one retrospective study that evaluated the safety issues (leukocytopenia or hyperkalemia) of NM anticoagulation, the benefits of NM appear to outweigh the potential risks. Minimal additional cost needs to be considered for the cost of NM compared to no anticoagulation.

8.5.2) Patients' values and preferences

From an economic perspective, the use of NM may increase the burden of costs and patients may prefer no anticoagulation. However, when NM was used, the total number of filters used during CKRT was significantly reduced, so if the filter cost reduction is deducted from the increase in NM cost, there may be no difference in patient preference in terms of economy.

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8.5.3) Obstacles and solutions

When NM is used as a CKRT anticoagulant, there are fewer practical barriers to its use, since the administration method is very simple without requirement of monitoring. However, clinical trials or observational studies with NM were only conducted in Korea or Japan, and no data is available for patients outside of Asia. Therefore, special consideration is needed when extrapolating these findings to non-Asian patients.

8.5.4) Resources

The use of NM itself can increase the burden of medical cost. However, one previous RCT showed that the total number of filters during CKRT was significantly reduced after the use of NM. Therefore, if the filter cost reduction is deducted from the increase in NM cost, there may be no difference in total medical cost. Recent availability of nafamostat-biosimilar agents can also reduce the burden of medical cost, although one retrospective study raised the concerns on the decreased efficacy with biosimilar agents. Extended filter life with NM may reduce the workload of medical staff for filter change or CKRT priming, which may eventually result in the reduction of total medical cost.

Key Question 9

9.1) PICO question

(P) In patients undergoing CKRT, does (I) ultrasound-guided dialysis catheter insertion, compared with (C) non-ultrasound-guided catheter insertion, improve (O) catheter insertion success rates and reduce complications?

9.2) Recommendation

In patients undergoing CKRT, ultrasound-guided hemodialysis catheter insertion is recommended.

9.3) Summary of recommendation statements

1. In patients undergoing CKRT, the use of ultrasound guidance for hemodialysis catheter insertion shows a relatively higher overall success rate compared to the insertion method using anatomical landmarks.
2. In patients receiving CKRT, the insertion of a hemodialysis catheter using ultrasound guidance has a lower likelihood of complications such as arterial puncture compared to insertion using anatomical landmarks.
3. In patients receiving CKRT, the use of ultrasound guidance for hemodialysis catheter insertion has a higher success rate on the first cannulation attempt than the insertion method based on anatomical landmarks.

Evidence level: High

Strength of recommendation: A (Strong recommendation)

9.4) Rationale

The necessity for precise catheter placement in CKRT cannot be overstated, as the ramifications of incorrect insertion are 2-fold: the immediate inability to provide essential therapy and the heightened risk of adverse events, which can compound a patient's critical condition. Catheter insertion without complication is not merely a procedural success; it is a critical determinant in the trajectory of a patient's recovery.

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The advent of ultrasound-guided catheter insertion has been a paradigm shift in managing critically ill patients requiring vascular access [110]. This technology offers real-time visualization, enabling clinicians to navigate anatomical variations and avoid structures that could lead to complications. The precision afforded by this method has been corroborated by numerous studies showing substantial improvements in first-attempt success rates and a notable decrease in complications, such as hematoma formation, infection, and thrombosis, often associated with traditional landmark techniques [111].

Consequently, ultrasound-guided central venous catheter insertion has become the standard treatment [112,113]. Therefore, there has been an increase in the use of ultrasound guidance for inserting hemodialysis catheters necessary for CKRT [114]. However, currently, there is not a high level of evidence supporting this practice. This clinical guideline examines 7 RCTs to consider whether using ultrasound guidance for inserting hemodialysis catheters for acute hemodialysis is beneficial compared to using anatomical landmarks.

The ultrasound-guided insertion method showed a higher overall success rate in all the randomized trials examined (**Supplementary Fig. 3**, KQ9) [114-120]. When pooled, ultrasound guidance increased the overall success rate more than tenfold and the first-attempt success rate by approximately 6-fold. Across the 7 reviewed studies, the major complications associated with CKRT catheter insertion can be categorized into mechanical/traumatic events (arterial puncture, hematoma, pneumothorax, hemothorax, catheter malposition, bleeding at the incision site, and nerve irritation), infectious complications (exit-site infection and catheter-related bloodstream infection), thrombotic events (venous thrombosis and, rarely, pulmonary embolism), and procedure-related issues such as severe insertion-site pain and cannulation failure, which can increase the risk of subsequent adverse outcomes. Complications were reduced by about 80%, and arterial puncture risk was decreased by approximately 83% compared with the anatomical landmark technique. Consequently, in patients undergoing CKRT, ultrasound-guided insertion of hemodialysis catheters can improve the success rate of catheter insertion and reduce complications compared to methods not using ultrasound guidance.

Recent studies conducted after 2010 provide additional insights that align with these findings while also highlighting some nuanced differences. For instance, the 2020 study by Ehtesham [114], focusing on internal jugular vein (IJV) cannulation, reported a 100% success rate for ultrasound-guided cannulation compared to 95.6% for the anatomical landmark method, with no statistically significant difference ($p = 0.494$). This suggests that experienced clinicians can achieve success rates with anatomical landmarks nearly comparable to those achieved with ultrasound guidance. This result contrasts with many older studies, which often showed a more marked difference favoring ultrasound, likely reflecting improved training and standardization in using anatomical landmarks over time. Despite these comparable success rates, ultrasound guidance still demonstrated a clear advantage in reducing complications, emphasizing its continued importance, especially in settings where variability in complication rates could pose significant risks.

Similarly, the 2013 study by Lam and colleagues [118], which examined femoral vein cannulation for acute hemodialysis access, found a success rate of 100% with ultrasound guidance versus 92% with anatomical landmarks, with a statistically significant difference ($p = 0.002$). While this study's results are consistent with earlier findings that demonstrated the challenges of using anatomical landmarks alone, it also highlights that anatomical

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techniques can still achieve high success when performed by skilled and experienced physicians, although with a greater risk of complications. The included RCTs demonstrated a low risk of bias and consistent beneficial effects, allowing the evidence to be graded as 'high.' Because the likelihood of harm was extremely low and the magnitude of benefit was substantial, a strong recommendation was justified.

9.5) Considerations

9.5.1) Benefits and harms

The utilization of ultrasound in catheter placement not only appears to enhance the success rate compared to the use of anatomical landmarks but also offers the significant benefit of reducing the time required for the insertion procedure. Additionally, the incidence of complications associated with vascular catheter insertions is reduced in patients with ultrasound, making it a safer option than the traditional landmark method.

However, some recent studies have reported a possible increase in central line-associated bloodstream infections (CLABSIs) during ultrasound-guided insertions. This increase in risk is likely attributable to inadequate aseptic handling of the ultrasound probe [121].

Randomized studies focusing on hemodialysis catheter insertions have not reported increased central line infections when ultrasound guidance is used compared to anatomical landmarks. This suggests that with adequate training and adherence to aseptic protocols, the risk of infection can be mitigated. When conducted correctly, ultrasound-guided catheter insertion stands as a significant improvement over older methods, providing clear benefits in terms of both success rates and safety.

9.5.2) Patients' values and preferences

Patients typically favor approaches that minimize discomfort, reduce the risk of complications, and shorten the duration of medical interventions. Ultrasound guidance, by offering a higher probability of successful catheter placement on the first attempt, not only lessens the anxiety associated with repeated procedures but also reduces the potential for pain and injury from multiple insertion attempts. Furthermore, the diminished risk of complications such as infections, arterial puncture, and other vascular injuries is particularly reassuring to patients, who often prioritize safety and the avoidance of additional medical issues. This method also allows for a more personalized treatment approach, as ultrasound can accommodate individual anatomical variances, thus reflecting a patient-centered approach to care that values the unique needs and physical circumstances of each patient. Therefore, when informed of the benefits and risks of both techniques, many patients are likely to prefer ultrasound-guided catheter insertion, valuing its precision, safety profile, and overall contribution to a more positive healthcare experience.

9.5.3) Obstacles and solutions

The method of ultrasound-guided hemodialysis catheter insertion, when compared to the technique using anatomical landmarks, requires training for the operators, who may need to become more familiar with it and necessitates ultrasound equipment [113]. However, in Korea, CKRT is performed exclusively in ICUs, and currently, tertiary hospitals are mostly equipped with ultrasound devices needed for catheter insertion. In addition, there is a growing trend of intensivists who are skilled in ultrasound-guided procedures, and most residents in tertiary hospitals receive training in ultrasound techniques for a certain period before starting their work in the ICU.

9.5.4) Resources

For inserting a hemodialysis catheter using ultrasound guidance, additional equipment such as the ultrasound machine itself, as well as sterile covers for the ultrasound probe and ultrasound gel, are necessary to maintain asepsis during the procedure. However, despite these additional requirements, ultrasound guidance also has advantages from a cost-effectiveness standpoint. It can save on the costs and medical personnel resources that would otherwise be expended in treating the various complications associated with the anatomical landmark method, including arterial punctures that can occur during catheter insertion [123,124].

9.5.5) Others

The absence of increased CLABSIs in studies included in the meta-analysis [114-120] likely stems from the rigorous adherence to aseptic procedures during ultrasound-guided insertions. This underscores the importance of meticulous attention to aseptic technique when performing ultrasound-guided procedures. Proper training in both aseptic techniques and ultrasound guidance is vital for clinicians performing these procedures to ensure patient safety and reduce the risk of infection [121]. This approach helps minimize the risk of infection and maximizes the overall success and safety of the catheter insertion process.

In ultrasound guidance for central venous catheter insertion, there are two main techniques: static and dynamic [124]. Static guidance involves using ultrasound to identify and mark the vessel's location before the needle insertion, allowing the procedure to proceed with removing the ultrasound probe. In contrast, dynamic guidance involves real-time monitoring where the ultrasound is used continuously during the needle insertion, providing a live view of the needle's progression toward the vessel. For novice practitioners, dynamic guidance can be more difficult due to the simultaneous manipulation of the needle and probe, requiring coordination and experience. Therefore, it is recommended that novices begin with static guidance to build their skills and confidence. Once they are proficient, they can transition to dynamic guidance, which, while more complex, offers the advantage of real-time feedback and potentially higher success rates.

When considering ultrasound guidance for catheter placement in different central veins, ultrasound guidance is advantageous and often necessary for both IJV and femoral vein catheterizations. However, the necessity of its use may be higher in IJV catheterization due to the potential for more serious complications without real-time visualization [125]. In femoral vein catheterization, although ultrasound is recommended, especially for novices or in difficult cases, it is sometimes considered optional depending on the clinical scenario and the operator's experience.

Comparing the complication rates without ultrasound guidance (using anatomical landmarks) between the internal jugular and the femoral veins in studies included in the meta-analysis reveals notable differences [114-120]. The complication rates for the IJV vary widely, ranging from 5% to 35.7%, indicating significant variability when using anatomical landmarks. In contrast, the femoral vein shows more consistent complication rates, ranging from 13.6% to 18.4%, although these rates are generally higher than the lowest rates seen in IJV studies (not statistically significant). This suggests that while femoral vein catheterizations using anatomical landmarks tend to be more predictable, IJV catheterizations, in some cases, demonstrate the potential for very high complication rates. The observed variability in IJV complications underscores the importance of ultrasound guidance, particularly for the IJV, where complications can be more unpredictable and potentially severe.

Key Question 10

10.1) PICO question

(P) In adult patients with AKI receiving CKRT, does (I) providing nutrition tailored to calorie, protein, vitamin, and trace element requirements, compared with (C) not doing so, improve (O) survival rates?

10.2) Recommendation

In adult patients with AKI receiving CKRT, it is recommended to provide 20–35 kcal/kg/day of energy (with a minimum of 12 kcal/kg/day), 1.2–2.5 g/kg/day of protein (with a minimum of 0.5 g/kg/day), and to monitor and supplement multivitamins and trace elements (including selenium, zinc, and copper) as needed.

10.3) Summary of recommendation statements

1. In adult patients undergoing CKRT, protein intake below 0.5 g/kg/day and energy intake below 12 kcal/kg/day may be associated with increased mortality.
2. Increasing protein intake to at least 1.2 g/kg/day may help reduce mortality.

Evidence level: Low

Strength of recommendation: B (Conditional recommendation)

10.4) Rationale

10.4.1) Proteins

In critically ill patients, amino acid and protein losses occur at a rate of 1.3–1.8 g/kg/day in the catabolic state. In patients with AKI receiving KRT, protein losses can reach up to 15 g/day [126-129]. In the RENAL trial by Bellomo et al. [130], patients were stratified by median daily protein intake (0.5 g/kg/day). No significant differences were observed between lower versus higher intake groups in 90-day mortality, ICU or hospital length of stay, CKRT duration, or duration of mechanical ventilation [130]. In contrast, Kritmetapak et al. [131] identified dietary protein intake below 0.8 g/kg/day as a predictor of mortality. In Bufarah's 2018 observational study [132], protein intake of 0.5 g/kg/day or lower was identified as a predictor of in-hospital mortality. van Ruijven et al. [133] found that achieving a protein intake ≥ 1.2 g/kg/day by ICU day 4 during CKRT was associated with reduced mortality. The recent EFFORT Protein study [134] investigated a higher protein target 1.2 versus 2.5 g/kg/day in ventilated patients with AKI. In the overall cohort, higher protein intake was associated with increased mortality. However, in the dialysis subgroup, no significant difference was observed, suggesting that substantial protein supplementation in CKRT patients may help offset dialysis-related protein losses [134]. Additionally, previous studies have reported that CKRT patients receiving mechanical ventilation require protein intake up to 2.5 g/kg/day to achieve nitrogen balance and avoid a negative nitrogen balance [135,136]. A meta-analysis of 4 major studies (2 large retrospective studies and 2 RCTs, excluding case reports and small observational studies) demonstrated that insufficient protein intake compared to estimated requirements was associated with an OR of 0.74 for survival (95% CI, 0.56 to 0.98), confirming the significance of adequate protein provision. This suggests that supplying protein in accordance with patient requirements in CKRT patients may reduce mortality by 26%. However, the included studies did not have standardized protein intake criteria, and there was no consistent assessment of the

timing or variations in protein administration, indicating the need for further research in this area. European Society for Clinical Nutrition and Metabolism (ESPEN) recommends a protein intake of 1.5–1.7 g/kg/day, while American Society for Parenteral and Enteral Nutrition suggests 2.0–2.5 g/kg/day. According to the 2016 Japanese guidelines, non-dialysis AKI patients should receive 0.8–1.0 g/kg/day, whereas dialysis-dependent patients should receive 1.7 g/kg/day. The Taiwan Society of Nephrology recommends a protein intake of 1.2–2.0 g/kg/day [10,127-129].

10.4.2) Calories

All patients expected to stay in the ICU for more than 48 hours should undergo a comprehensive nutritional assessment, and their nutritional requirements should be gradually provided to meet their needs [126-128,137-140]. It is not recommended to immediately provide 100% of the estimated nutritional requirements. Instead, during the first week of ICU admission, energy intake should be gradually increased, typically to < 20 kcal/kg/day or 80% of the estimated requirement. Bufarah et al. [132] identified energy intake < 12 kcal/kg/day as a predictor of mortality. Macias et al. [141] recommended a caloric intake target of 25–35 kcal/kg/day. In CKRT patients, additional caloric contributions from dialysate and replacement solutions should be considered, in addition to enteral/parenteral nutrition, antibiotics, and sedatives. Depending on CKRT prescription, these may provide an extra 200–500 kcal/day [138]. While citrate is not used as an anticoagulant in South Korea, its use would add approximately 3 kcal/kg/day and should be included in total energy calculation [128].

10.4.3) Vitamins and trace elements

Several observational studies have reported significant losses of trace elements and water- and fat-soluble vitamins during CKRT [142-144]. There is currently insufficient evidence to confirm that additional supplementation leads to improved survival rates. However, ESPEN recommends maintaining the following supplementation regimen: vitamin B1 (thiamine) 100 mg/day, vitamin B2 (riboflavin) 2 mg/day, vitamin B3 (niacin) 20 mg/day, vitamin B5 (pantothenic acid) 10 mg/day, vitamin B6 (pyridoxine) 100 mg/day, vitamin B7 (biotin) 200 μg/day, folic acid 1 mg/day, vitamin B12 (cobalamin) 4 μg/day, vitamin C 250 mg/day, selenium 100 μg/day, zinc 50 mg/day, and copper 5 mg/day [128]. Recent studies have also suggested the necessity of supplementing fat-soluble vitamins and additional trace elements, including: vitamin E 20 mg/day, vitamin K 4–10 mg/day, chromium 15 μg/day, fluoride 0–1 mg/day, iodine 130 μg/day, iron 1 mg/day, manganese 55 μg/day, and molybdenum 19–25 μg/day; In addition, the need for carnitine supplementation has also been proposed [126,137,145].

10.5) Considerations

10.5.1) Benefits and harms

In adult AKI patients receiving CKRT, inadequate protein provision should be avoided. Additionally, vitamins and trace elements should be supplemented, considering losses that occur during dialysis.

10.5.2) Patients' values and preferences

Enteral nutrition is generally preferred for patients with preserved consciousness and gastrointestinal function.

10.5.3) Obstacles and solutions

In patients undergoing CKRT, accurately estimating nutritional requirements can be

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challenging. Available assessment methods, including plasma albumin, prealbumin levels, comprehensive nutritional assessments, nitrogen balance studies, and indirect calorimetry, can be utilized; however, their advantages and limitations must be carefully considered. When supplementing trace elements and vitamins, contamination risks associated with mixing them into parenteral nutrition formulations should be taken into account. Optimal dosing, administration routes, and timing require further investigation.

10.5.4) Resources

A meta-analysis of 4 studies demonstrated that insufficient protein intake compared to estimated requirements was associated with an OR of 0.74 for mortality (95% CI, 0.56 to 0.98), highlighting the importance of adequate protein provision.

Key Question 11

11.1) PICO question

(P) In patients with AKI before liver transplantation, does (I) performing CKRT during surgery, compared with (C) not performing CKRT, result in (O) differences in survival rates?

11.2) Recommendation

The application of CKRT during surgery in patients with AKI before liver transplantation should be individualized based on the patient's severity and fluid status.

11.3) Summary of recommendation statements

1. In patients with AKI before liver transplantation, there was no significant difference in post-transplant survival rates between the group that received CKRT during surgery and the group that did not.
2. The group that underwent CKRT during surgery had significantly higher severity of illness compared to the group that did not receive CKRT.

Strength of recommendation: Expert consensus

11.4) Rationale

AKI is one of the most common complications in patients with end-stage liver disease. If AKI is not appropriately treated or does not respond to treatment, it may progress to HRS. The only treatment that can improve long-term survival in HRS is liver transplantation. However, pre-transplant kidney dysfunction can impact post-transplant survival and the occurrence of complications. Approximately 13–20% of liver transplant recipients experience AKI before transplantation [146,147]. Patients who are already receiving RRT before transplantation or those at high risk of fluid overload, portal hypertension, and pulmonary edema at the time of transplantation may undergo intraoperative CKRT. Intraoperative CKRT facilitates fluid management, removal of metabolic waste products such as uremic toxins, and correction of electrolyte imbalances. Additionally, it helps alleviate the hemodynamic burden associated with reperfusion [148,149]. Despite these advantages, clear criteria for the application of intraoperative CKRT in this patient group have not yet been established.

In this clinical guideline, recent literature on this patient group was analyzed to evaluate the efficacy of intraoperative CKRT during liver transplantation. A total of 6 observational studies and 1 pilot RCT were reviewed. The analysis revealed no significant difference in

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survival rates between the group that received intraoperative CKRT and the group that did not (**Supplementary Fig. 3**, KQ11). The pilot RCT was prematurely terminated due to difficulties in patient enrollment and showed no significant differences in mortality or perioperative complications between the 2 groups [150]. A meta-analysis of retrospective observational studies, categorized based on follow-up duration, was conducted to assess survival rates. The results showed a trend toward higher survival rates in the control group compared to the intraoperative CKRT group at 30 and 90 days; however, these differences were not statistically significant. In contrast, at the 1-year follow-up, survival rates were significantly lower in the CKRT group [151-156]. However, the treatment group had significantly higher severity indicators compared to the control group, including the Model for End-Stage Liver Disease (MELD) score, vasopressor requirements, and preoperative ICU admission rates. Notably, according to a domestic study that carried the highest weight in the meta-analysis, the group that underwent intraoperative CKRT had significantly higher MELD scores, preoperative renal failure rates, mechanical ventilation requirements, and ICU admission rates. Consequently, this group demonstrated poorer outcomes in terms of patient survival, graft survival, renal function recovery, and postoperative complications. However, the CKRT group experienced significantly lower rates of fluid overload after surgery and excessive sodium fluctuations during the procedure [8]. Meanwhile, when comparing patients who underwent intraoperative CKRT as an emergency intervention during surgery with those who received planned CKRT preoperatively, the emergency CKRT group showed significantly higher mortality rates, longer hospital stays, and increased incidence of severe postoperative complications [152,154].

Due to the limitations of observational studies, including the high risk of selection bias and confounding variables, the following expert consensus recommendation is provided: intraoperative CKRT may be considered for patients requiring RRT before liver transplantation, those expected to have significant fluid overload and high transfusion requirements, and patients with high vasopressor demands or requiring mechanical ventilation. Further prospective studies are needed to gather more robust evidence and establish appropriate indications for this therapy.

11.5) Considerations

11.5.1) Benefits and harms

In patients with AKI before liver transplantation, performing intraoperative CKRT offers advantages over not performing it in terms of fluid management, electrolyte balance, and the removal of ammonia, lactate, and uremic toxins. However, it also increases the risk of catheter-related bleeding and infections, while requiring additional human and material resources, leading to increased costs.

11.5.2) Patients' values and preferences

From the patient's perspective, there is generally no specific value or preference regarding the use of intraoperative CKRT. Instead, the decision to implement this treatment is typically based on the medical judgment of healthcare professionals.

11.5.3) Obstacles and solutions

No significant barriers are anticipated in applying this recommendation in clinical practice.

11.5.4) Resources

CKRT is a readily available resource in medical institutions currently performing liver transplantation in the country.

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Key Question 12

12.1) PICO question

(P) In acute brain injury patients with concurrent AKI, does (I) CKRT provide more favorable (O) outcomes for the patient (including intracranial pressure [ICP] control, renal function recovery, and mortality) compared to (C) IHD?

12.2) Recommendation

In acute brain injury patients who develop AKI requiring RRT, CKRT may be prioritized based on the patient's clinical condition and circumstances.

12.3) Summary of recommendation statements

1. In patients with acute brain injury and concurrent AKI, small-scale studies have shown that CKRT results in lower fluctuations in ICP and more stable cerebral perfusion pressure (CPP) compared to IHD.
2. CKRT may offer advantages over IHD in terms of renal function recovery, based on available evidence.

Strength of recommendation: Expert consensus

12.4) Rationale

Acute brain injury can occur due to various causes, including acute ischemic stroke, traumatic brain injury, cerebral hemorrhage, encephalitis, hypoxic-ischemic brain injury, brain tumors, and others. In critically ill patients with concurrent acute brain injury, both neurological and non-neurological complications become important factors determining the prognosis [157]. In patients with acute brain injury, multiple organ dysfunction can occur, with AKI being one of them [158]. In neurocritical care patients, the occurrence of AKI has been reported to be approximately 11%, irrespective of the specific type of brain injury [159]. However, when considering the frequency according to the type of acute brain injury, it has been reported to vary as follows: 9.2% for traumatic brain injury [160], 14.5% to 20.9% for acute ischemic stroke [161,162], 19% for cerebral parenchymal hemorrhage [163], and 12% to 23.1% for subarachnoid hemorrhage [164,165].

In acute brain injury patients, the etiology of concurrent AKI varies depending on the type of brain injury [166]. Traumatic brain injury is associated with AKI primarily due to trauma-induced bleeding, rhabdomyolysis, sepsis, excessive sympathetic nervous system activation, and drug-induced acute interstitial nephritis [167]. Subarachnoid hemorrhage patients commonly experience AKI due to sepsis, hypernatremia, hyperchloremia, contrast-induced nephropathy, and drug-induced acute interstitial nephritis [168,169]. In patients with ischemic stroke or cerebral parenchymal hemorrhage, AKI typically arises from reduced renal perfusion, sepsis, contrast-induced nephropathy, and drug-induced acute interstitial nephritis [170,171].

In the presence of AKI, clinical symptoms such as elevated urea levels, electrolyte imbalances, metabolic acidosis, and fluid overload can manifest, with their severity typically corresponding to the degree of renal impairment [172]. Therefore, severe cases of AKI may necessitate RRT, offering options like IHD and CKRT. IHD relies on diffusion to rapidly remove waste solutes and excess fluids over several hours, addressing metabolic acidosis and

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electrolyte imbalances. In contrast, CKRT employs both diffusion and convection methods, gradually eliminating solutes and fluids over a 24-hour period, effectively managing acid-base disturbances and electrolyte abnormalities [173]. Consequently, CKRT provides greater hemodynamic stability compared to IHD, leading to a more gradual changes in solute concentrations in the bloodstream [174]. Therefore, reports indicate that the application of continuous RRT in patients with concomitant brain injury facilitates ICP control and maintains stable cerebral blood flow and CPP, thereby offering the advantage of preventing secondary brain injury in the majority of patients [175,176]. In patients with AKI and hepatic encephalopathy due to fulminant hepatic failure, those receiving IHD showed a significant increase in ICP from 9 ± 1.4 mmHg to 13 ± 1.8 mmHg within the first hour, and a decrease in mean arterial pressure (MAP) from 92.4 ± 2.7 mmHg to 81 ± 3.2 mmHg, leading to up to a 30% reduction in CPP. Conversely, patients treated with CKRT, despite higher baseline ICP (19 ± 4.8 mmHg) and lower MAP (66 ± 3.6 mmHg), exhibited no significant changes in ICP, MAP, or CPP during treatment [177]. In response to these findings, the clinical guidelines committee aimed to recommend suitable dialysis modalities and establish the supporting evidence for cases where RRT is necessary in acute brain injury patients with concurrent AKI. The goal was to potentially enhance patient outcomes, encompassing ICP management, renal function recovery, and mortality.

The clinical guidelines committee conducted a search on September 21, 2023, utilizing Ovid Medline, Embase, Cochrane Library, and KMbase to address the core questions. A total of 211 research papers were identified. After eliminating duplicates, 186 references were screened, and 10 full-text articles were assessed. Ultimately, a single retrospective observational study was selected [178]. A study conducted in Taiwan reported that in patients with concurrent traumatic intracranial hemorrhage and AKI, CKRT demonstrated superior outcomes in terms of renal function recovery compared to IHD. The risk of dialysis dependency was significantly lower in the CKRT group compared to the IHD group (95% CI, 0.15 to 80.858; p = 0.034) [178]. Subsequently, expert consensus recommendations were formulated by comprehensively analyzing the relevant data pertaining to the key questions.

During IHD, various blood constituents, including sodium and other osmotically active particles, are rapidly removed from the bloodstream. However, due to the presence of the blood-brain barrier, the clearance of these particles from the brain occurs at a relatively slower rate. This discrepancy creates an osmotic gradient between the serum and the cerebral extracellular environment, leading to the diffusion of water into the brain. Consequently, ICP increases, potentially resulting in dialysis disequilibrium syndrome and cerebral edema [179,180]. Furthermore, IHD may be linked to a higher incidence of intradialytic hypotension compared to CKRT. Intradialytic hypotension can reduce CPP, triggering compensatory cerebral vasodilation and subsequently raising ICP [181,182]. Therefore, in acute brain injury patients with elevated ICP, CKRT offers greater stability with reduced fluctuations in both ICP and CPP compared to IHD [183-185]. However, a case report noted that ICP increased even in a 13-year-old female patient undergoing CKRT. Based on the collective evidence, a systematic review and meta-analysis reported that CKRT reduces both the incidence of ICP elevation and mortality compared to IHD in patients with end-stage kidney disease and acute brain injury [186]. Moreover, when IHD is the only viable option for end-stage renal disease patients with concurrent acute brain injury, it is recommended to mitigate hemodynamic instability by minimizing fluctuations in effective blood volume through the utilization of a high-sodium concentration and cooled dialysate [175,187]. In addition, for patiens with existing intracranial hemorrhage or a significant bleeding tendency, an

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anticoagulant-free CKRT protocol is advised. Close collaboration with a nephrology specialist is mandatory in these scenarios.

When AKI occurs in acute brain injury patients, requiring RRT, the clinical evidence supporting the selection of the appropriate dialysis modality to improve patient outcomes relies primarily on a single retrospective observational study. Nevertheless, when considering the mechanisms of action and research findings involving both IHD and CKRT in end-stage renal disease patients, CKRT is anticipated to be more advantageous for patient outcomes than employing IHD.

12.5) Considerations

12.5.1) Benefits and harms

When AKI accompanies acute brain injury, there is a lack of direct evidence to support the selection of the most beneficial RRT for improving patient outcomes. However, studies have reported favorable outcomes when applying CKRT in end-stage renal disease patients with concurrent acute brain injury. Therefore, it is anticipated that the use of CKRT is more advantageous for patient outcomes compared to IHD. Nevertheless, the decision should be based on a comprehensive assessment of the patient's clinical condition.

12.5.2) Patients' values and preferences

While there may be variability in values and preferences due to the patient's severity, there is insufficient available evidence. Therefore, it is necessary to make medical judgments based on the patient's clinical condition and consider individualized treatment.

12.5.3) Obstacles and solutions

CKRT is a costly medical intervention. Hence, when considering its application, shared decision-making with the patient and caregivers is crucial. Additionally, it is essential to consider the expertise, equipment, facilities, and management capabilities available within each healthcare institution.

12.5.4) Resources

The application of CKRT can place an additional burden on healthcare professionals in the clinical setting and lead to increased healthcare costs for patients. Therefore, decisions regarding its use should be made based on the patient's severity of illness and clinical condition.

Key Question 13

13.1) PICO question

(P) In patients receiving ECMO, does (I) the use of CKRT improve (O) patient outcomes, compared to (C) not using CKRT?

13.2) Recommendation

We cannot decide whether or not CKRT should be used in patients on ECMO who have not developed AKI due to the very low level of evidence.

13.3) Summary of recommendation statements

1. In patients undergoing ECMO, the use of CKRT resulted in higher mortality rates and lower ECMO weaning rates compared to not using CKRT. Additionally, both ECMO duration and length of hospital stay were longer.

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2. However, it's worth noting that most of the available evidence comes from retrospective cohort studies, and the analysis primarily focused on assessing the frequency of CKRT (for treating AKI) as part of ECMO complications rather than conducting direct comparisons between CKRT and non-CKRT groups.
3. Therefore, until additional evidence becomes available, an individualized approach based on the patient's clinical condition is advisable, especially for patients who have not developed AKI.

Evidence level: Very low

Strength of recommendation: I (Inconclusive)

13.4) Rationale

ECMO is a form of life-support therapy and its use has been increasing worldwide each year [174]. ECMO can assist cardiac or pulmonary function through an extracorporeal circulation technique in patients with severe heart failure or acute respiratory failure refractory to standard therapy. However, AKI is quite common in ECMO patients, and CKRT is often applied to patients with fluid overload. The application of CKRT solely for fluid balance in the absence of clear evidence of AKI raises concerns regarding the potential overuse of limited medical resources. This clinical practice guideline was developed to determine whether the use of CKRT in critically ill patients receiving ECMO improves clinical outcomes, and to provide practical support for healthcare professionals in making informed clinical decisions about whether to implement CKRT concurrently in patients undergoing ECMO.

In accordance with our literature search strategy, we identified a total of 4,327 articles, excluding duplicates, from the initial pool of 4,381 articles. Subsequently, we conducted a screening process based on titles and abstracts, selecting 120 articles for further evaluation. Upon reviewing the full texts and applying our predefined inclusion and exclusion criteria, we ultimately narrowed down our selection to 44 articles. All 44 papers are cohort studies, with one of them being a prospective study [188]. The one prospective study was conducted in a pediatric population [189].

A total of 44 studies reported mortality rates, with hospital mortality rates reported in 36 papers [189-224]. The remaining studies reported mortality rates at 30 days [226], 90 days [226], and 6 months [188], each in one study. Additionally, 1-year mortality rates were reported in two studies [227,228], and ICU mortality rates were reported in three studies [229-231]. The pooled RR for mortality in the CKRT group, compared to the non-CKRT group, was 1.83 (95% CI, 1.64 to 2.03) (**Supplementary Fig. 3**, KQ13).

The rate of ECMO weaning was reported in 3 studies [199,211], and the rate was lower in the CKRT group, compared to the non-CKRT group (RR, 0.79; 95% CI, 0.69 to 0.90). ECMO duration was reported in 5 studies [198,199,211,219,229] and was significantly longer in the CKRT group, compared to the non-CKRT group (MD, 1.66; 95% CI, 0.23 to 3.08). The length of hospital stay was reported in 2 studies [199,212] and was longer in the CKRT group, compared to the non-CKRT group (MD, 4.86; 95% CI, 0.12 to 9.59).

However, it's worth noting that most of the studies were retrospective cohort studies, and there were insufficient direct comparative studies between the CKRT group and non-CKRT group. In most of the studies, CKRT was initiated due to the progression of AKI, and only simple

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comparisons in the frequency of CKRT were made between the survival and non-survival groups. Consequently, it is highly likely that the CKRT group had a higher severity, compared to the non-CKRT group, reducing the comparability between the 2 groups. As a result, although the implementation of CKRT may be necessary in patients on ECMO who have developed AKI for fluid management, metabolic acidosis treatment and etc.; we could not decide whether the treatment should be used in patients on ECMO who have not developed AKI.

The primary outcome measure was the mortality rate. However, because all 44 selected studies were cohort studies, we downgraded by one step due to the 'risk of bias' domain. Additionally, due to concerns regarding 'indirectness' and 'imprecision,' we downgraded by one step in each domain. Based on these factors, the overall level of evidence for this clinical question was assessed as 'very low.'

13.5) Considerations

13.5.1) Benefits and harms

In patients receiving ECMO who are at high risk of fluid overload or currently present with pulmonary edema or fluid overload, the concurrent use of CKRT may be beneficial for maintaining fluid balance. However, the requirement for additional catheter insertion or connection can increase the risk of complications, including disturbances in blood flow, thrombosis, hemolysis, and infection. In order to properly evaluate the effectiveness of concurrent CKRT in patients receiving ECMO, prospective RCTs or severity-adjusted comparative studies are required. It is important to note that a significant portion of the literature included in this analysis reported the use of CKRT during ECMO treatment. This suggests that the CKRT group had a higher severity, compared to the non-CKRT group, potentially resulting in less favorable treatment outcomes. Therefore, considering there is insufficient evidence, the decision on the use of CKRT in ECMO patients without AKI should be based on comprehensive evaluation of the patient's clinical status and prognosis.

13.5.2) Patients' values and preferences

CKRT is considered an essential therapeutic modality for patients in the ICU who are experiencing conditions such as acid-base imbalances, oliguria, fluid overload, and AKI. However, it is worth noting that CKRT, like ECMO, is also a high-cost therapeutic modality. Both ECMO and CKRT are reserved for severely ill patients in the ICU, which may limit patient autonomy in the decision-making process. Considering the current lack of strong evidence regarding the combined use of ECMO and CKRT, it is advisable to make decisions based on a comprehensive assessment of the patient's condition and prognosis rather than routinely implementing CKRT in ECMO patients.

13.5.3) Obstacles and solutions

ECMO and CKRT are both treatments that involve significant medical expenses. Therefore, it is essential for healthcare personnel to engage in comprehensive discussions with patients and their caregivers regarding the decision to proceed with CKRT. Furthermore, it is necessary to fully consider the personnel, equipment, and facilities available at each healthcare institution.

13.5.4) Resources

Providing CKRT to ECMO patients can place additional demands on healthcare personnel and may potentially increase the patient's medical costs, even if they have medical insurance coverage. In particular, in situations where there is a large surge in critically ill patients, the

efficient distribution of healthcare resources becomes highly crucial. To accomplish this, treatment decisions should be based on a careful consideration of the patient's severity of illness and their expected outcomes.

Key Question 14

14.1) PICO question

(P) In patients undergoing ECMO, does (I) the concurrent use of CKRT from the beginning improve the (O) patient's prognosis, compared to (C) initiating CKRT when the indications are met?

14.2) Recommendation

The decision to initiate CKRT early (concurrently) in patients undergoing ECMO treatment is deferred.

14.3) Summary of recommendation statements

1. In patients undergoing ECMO, the early initiation of CKRT (within 72 hours of ECMO initiation) did not show significant differences, compared to its delayed initiation in terms of mortality rates, lengths of hospital stay, ECMO weaning rates, or fluid balance. However, it is crucial to note that the existing literature is quite limited, and the number of included patients is small, indicating the need for further research in the future.
2. There is insufficient evidence to suggest that performing CKRT alongside ECMO treatment improves survival rates and other outcomes in patients without accompanying AKI.

Evidence level: Very low

Strength of recommendation: I (Inconclusive)

14.4) Rationale

ECMO is a form of life-support therapy and its use has been increasing worldwide each year [233]. ECMO can assist cardiac or pulmonary function through an extracorporeal circulation technique in patients with severe heart failure or acute respiratory failure refractory to standard therapy. However, AKI is quite common in ECMO patients, and CKRT is often applied to those patients to address fluid overload. In accordance with our literature search strategy, we identified a total of 4,327 articles, excluding duplicates, from the initial pool of 4,381 articles. Subsequently, we conducted a screening process based on titles and abstracts, selecting 120 articles for further evaluation. Upon reviewing the full texts and applying our predefined inclusion and exclusion criteria, we ultimately narrowed down our selection to 3 articles. Among these, one is a RCT [234], another is a retrospective cohort study conducted across three institutions that applied propensity score matching [234], and the remaining one is a single-center retrospective cohort study [235].

A total of 2 studies reported hospital mortality rates. The single-center pilot study (RCT) included 41 veno-arterial (VA) ECMO patients who were randomly allocated into 2 groups: the early CKRT group (initiated within < 12 hours of ECMO) and the standard treatment group (i.e., CKRT initiated upon meeting criteria). The hospital mortality rates were 11/21 (52.4%) and 14/20 (70.0%) in the early CKRT and the standard treatment group, respectively, with no significant difference between the 2 groups ($p = 0.340$) [233]. In the retrospective cohort

study conducted across three institutions, a total of 296 patients receiving VA or veno-venous ECMO underwent CKRT based on their fluid balance status. Propensity score matching was applied to compare 47 patients in the early CKRT group (initiated within 1.1 ± 0.9 days) with 47 patients in the late CKRT group (initiated within 14.6 ± 18.6 days). The hospital mortality rates were 28/47 (59.6%) and 27/47 (57.4%) in the early CKRT and the late CKRT groups, respectively, with no significant difference between the 2 groups (p = 0.834) [234].

The length of hospital stay was reported in the two studies. In the RCT, the length of hospital stay was 20.5 (15.8–29.3) days and 18.5 (9.5–26.3) days in the early CKRT and standard treatment groups (i.e., CKRT initiated upon meeting criteria), respectively, with no significant difference between the two groups (p = 0.34) [233]. In the retrospective cohort study across three institutions, utilizing propensity score matching, the early CKRT group (47 patients) and the late CKRT group (47 patients) had a hospital stay of 49.6 ± 70.5 and 43.8 ± 38.2 days, respectively, with no significant difference between the 2 groups (p = 0.627) [234].

ECMO weaning rates were reported in 2 studies, one being an RCT [233], and the other a single-institution retrospective cohort study [235]. In the RCT, the ECMO weaning rates were 14/21 (66.7%) and 10/20 (50.0%) in the early CKRT and the standard treatment group (i.e., CKRT initiated upon meeting criteria), respectively, with no significant difference between the groups (p = 0.35) [233]. The retrospective cohort study, conducted at a single institution, focused on 15 VA ECMO patients with stage 3 AKI according to the Acute Kidney Injury Network (AKIN) criteria. In this study, the ECMO weaning rates for the early CKRT group (within < 24 hours of AKI) and the late CKRT group were 3/8 (37.5%) versus 2/7 (28.6%), respectively, with no significant difference between the groups (p = 0.58) [235].

Fluid balance was assessed in 2 studies, one being an RCT [234], and the other a retrospective cohort study conducted across three institutions [234]. In the RCT, which compared the early CKRT group (21 patients) with the standard treatment group (20 patients), the third-day fluid balance was −1,510 (−3,560 to 1,162) and −332 (−2,027 to 2,180) mL, respectively. Although the early CKRT group showed a slightly lower (more negative) fluid balance, there was no statistically significant difference (p = 0.38) [233], In the retrospective cohort study across 3 institutions, where propensity score matching was used to compare the early CKRT group (47 patients) with the late CKRT group (47 patients), the third-day fluid balance was 108.3 ± 94.6 and 104.8 ± 110.0 mL/kg, respectively, with no significant difference between the groups (p = 0.868) [234].

The RCT and the retrospective cohort study performed in three institutions were reasonably aligned with the main research questions, and their comparisons between the 2 groups were appropriate. However, the remaining single-institution retrospective cohort study focused on patients with pre-existing AKI (AKIN stage 3) before ECMO initiation, which may not be directly relevant to the primary research questions. For reporting hospital mortality rates and length of hospital stay, both the RCT and the retrospective cohort study were assessed as having very low-quality evidence in the domains of 'inconsistency' and 'imprecision.' Likewise, in terms of ECMO weaning rates and fluid balance, the evidence quality was also assessed as very low due to inconsistency and imprecision.

14.5) Considerations

14.5.1) Benefits and harms

In ECMO patients, early CKRT may help effectively manage fluid balance, AKI, and acid-

base disturbances. Conversely, delayed initiation of CKRT allows sufficient time for natural kidney recovery. While some studies have suggested the possibility that early CKRT may aid in maintaining fluid balance [233], there remains insufficient evidence regarding the overall effectiveness of CKRT in ECMO patients. It is crucial to consider the risks associated with additional catheter insertion or connections, as well as potential complications such as hemolysis, clotting, infection, and disruptions to ECMO blood flow. It is uncertain to assess the risk and benefit due to the insufficient evidence of currently evaluated studies. Therefore, we conclude that the assessment of the benefit and harm of early vs. late CKRT is difficult, and more evidence is needed.

14.5.2) Patients' values and preferences

CKRT can be considered an essential therapeutic modality for patients in ICUs, addressing issues such as acid-base imbalances, fluid overload, and AKI. However, it is important to acknowledge that, like ECMO, CKRT is also a high-cost therapeutic modality. Both ECMO and CKRT are reserved for severely ill patients in the ICU, which may limit patient autonomy in the decision-making process. Considering the limited evidence regarding the combined use of ECMO and CKRT, it is essential to base decisions on a comprehensive assessment of the patient's condition and prognosis.

14.5.3) Obstacles and solutions

ECMO and CKRT are both treatments that involve significant medical expenses. Therefore, it is essential for healthcare personnel to engage in comprehensive discussions with patients and their caregivers regarding the decision to proceed with CKRT. Furthermore, it is necessary to thoroughly consider the personnel, equipment, and facilities available at each healthcare institution. The establishment of a well-structured care system, such as a dedicated team consisting of nurses or perfusionists capable of simultaneously managing ECMO and CKRT, as well as a multidisciplinary collaboration system involving nephrology and critical care medicine, can help overcome barriers to CKRT implementation and promote the delivery of appropriate care.

14.5.4) Resources

Providing CKRT to ECMO patients can place additional demands on healthcare personnel and may potentially increase the patient's medical costs, even if they have medical insurance coverage. In particular, in situations where there is a large surge in critically ill patients, the efficient distribution of healthcare resources becomes highly crucial. To accomplish this, treatment decisions should be based on a careful consideration of the patient's severity of illness and their expected outcomes.

Key Question 15

15.1) PICO question

(P) In pediatric patients with fluid overload due to AKI, is (I) early initiation of CKRT effective in improving (O) clinical outcomes compared to © late initiation of CKRT?

15.2) Recommendation

Early initiation of CKRT is recommended for pediatric patients with fluid overload due to AKI.

15.3) Summary of recommendation statements

1. In studies comparing the survivors and non-survivors of critically ill pediatric patients who received CKRT, CKRT was initiated at a lower level of fluid overload in the survivors.

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2. There is some evidence that early removal of fluid overload may be associated with a reduced risk of mortality.
3. The degree of fluid overload at which CKRT should be initiated depends on the target patient population.
4. There are no studies comparing pediatric patients with adults, and there are no RCTs (only observational studies), so the evidence remains inconclusive.

Strength of recommendation: Expert consensus

15.4) Rationale

Since the introduction of CKRT in the 1980s, CKRT has become an integral part of the treatment of critically ill pediatric patients [236]. AKI in critically ill pediatric patients is directly associated with increased mortality, and fluid overload in AKI is also one of the independent prognostic factors for mortality in critically ill pediatric patients treated in pediatric ICUs [238].

Although the use of CKRT in critically ill pediatric patients has increased significantly, the optimal timing of CKRT initiation in AKI remains undefined. Currently, the timing of CKRT initiation in AKI is left to the discretion of clinicians at each center and is often based on the severity of clinical features such as fluid overload, uremia, electrolyte imbalance, and severe acidosis. The 2012 AKI KDIGO guidelines recommended immediate initiation of CKRT in patients with life-threatening fluid accumulation, electrolyte, and acid-base imbalances, but otherwise recommended that initiation should be based on clinical presentation and not solely on blood urea and creatinine levels [238]. As a pediatric consideration, they noted that several studies have suggested that fluid overload is likely an important factor associated with pediatric mortality in AKI, but there is not yet strong evidence to assess this relationship [237-243].

Our systematic review identified a total of 18 studies on early initiation and outcomes of CKRT in pediatric patients, including the studies mentioned by KDIGO, all of which were observational studies and none of which were RCTs. In these 18 studies, meta-analysis was limited by heterogeneity in populations, inclusion criteria, and comparators across studies, but as noted by 2012 AKI KDIGO guidelines, in critically ill pediatric patients undergoing CKRT, when comparing survivors and non-survivors, it is reasonable to assume that early fluid removal would reduce the risk of mortality, given that CKRT is initiated when the degree of fluid overload is lower in the survivors [237-241,243-257]. The degree of fluid overload that significantly differentiated the survivors from the non-survivors in each study varied from 10% to 30%, so there is no single threshold for the degree of fluid overload that can be used as an indication to start CKRT. Taken together, these findings suggest that the tolerable level of fluid overload may vary depending on the patient population.

15.5) Considerations

15.5.1) Benefits and harms

The timing of initiation of CKRT in critically ill pediatric patients is thought to have benefits that outweigh harms, as early initiation of CKRT before severe fluid overload may reduce the risk of mortality. However, the threshold of fluid overload to define “early” has not been established, as it varies from study to study.

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15.5.2) Patients' values and preferences
Patients do not have a specific preference for the timing of CKRT, and the choice of when to start CKRT in the treatment of critically ill pediatric patients is usually based on the medical judgment of the healthcare provider.

15.5.3) Obstacles and solutions
For pediatric patients, the equipment and trained physicians required for CKRT are essential, but availability varies by institution. For early CKRT, domestic tertiary care centers that treat critically ill children may need physicians and equipment support.

15.5.4) Resources
Early CKRT initiation does not necessarily result in higher costs, as early CKRT can shorten the duration of CKRT and ICU stay. Therefore, cost should not be a deterrent to early CKRT.

Key Question 16
16.1) PICO question
(P) In patients on CKRT, does (I) nephrologist consultation improve (O) outcomes such as survival and complication rates compared to (C) not seeing a nephrologist?

16.2) Recommendation
In adult patients (≥ 18 years of age) on CKRT, referral to a nephrologist is recommended to improve prognosis.

16.3) Summary of recommendation statements

There are reports of significantly lower 30-day mortality in patients who were advised by a nephrologist after starting CKRT compared to patients in the non-consultation group. Strength of recommendation: Expert consensus

16.4) Rationale
Although advances in RRT and critical care management by multidisciplinary teams have significantly improved the survival of patients with AKI in the ICU, the prognosis of patients requiring CKRT for severe AKI remains poor [258-260]. Just as early management and referral to a nephrologist in patients with CKD can preserve residual renal function and improve patient outcomes [261,262], it has been reported that nephrologist involvement in severe AKI can improve patient survival [263,264]. In our review of existing guidelines for CKRT, we found no high-quality evidence, including randomized clinical trials, and one observational study [265] published in 2023 that analyzed the association of receiving advice from a nephrologist before and after CKRT with appropriate treatment initiation and maintenance with patient survival. The observational study reported that when comparing mortality at 30 days after CKRT initiation, the mortality rate was statistically significantly lower in the consultation group (64.1%) compared to the non-consultation group (86.1%) (hazard ratio [HR], 0.47; 95% CI, 0.40 to 0.56; $p < 0.001$) [265]. Furthermore, when patients were stratified into early and delayed consultation groups based on the median time of specialist consultation (10 hours), the early consultation group had approximately 5% lower mortality after CKRT than the delayed consultation group (HR, 0.45; [95% CI, 0.37 to 0.54] vs. HR, 0.51 [95% CI, 0.42 to 0.61], respectively) [8]. This may suggest that earlier consultation may

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contribute to improved survival after CKRT initiation, and consequently, multidisciplinary care, including consultation with a nephrologist, may be recommended when CKRT is indicated in patients with severe AKI.

16.5) Considerations

16.5.1) Benefits and harms

There have been no RCTs of nephrologist consultation in patients on CKRT, so it is not possible to definitively state the benefits or harms of specialist consultation in terms of improved outcomes such as survival and complication rates. However, given the suggested mortality benefit of seeking the advice of a nephrologist, as evidenced by the individual observational studies reviewed above, we believe that the benefits outweigh the expected harms.

16.5.2) Patients' values and preferences

Because the decision to consult with a nephrologist is typically based on the medical judgment of the healthcare provider, it is not meaningful to address patient values and preferences in this recommendation. However, multidisciplinary care that includes nephrologist consultation is expected to be consistent with patient values and preferences.

16.5.3) Obstacles and solutions

We do not believe there are any barriers to implementing this recommendation in practice, but consideration should be given to the cost of staffing and consultation by medical staff, including nephrologists.

Key Question 17

17.1) PICO question

(P) In patients receiving CKRT, does (I) a specialized or multidisciplinary team approach improve (O) clinical outcomes such as patient survival, filter lifespan compared with (C) no specialized team approach?

17.2) Recommendation

To improve filter lifespan and to reduce downtime in critically ill patients requiring CKRT, a specialized or multidisciplinary team approach tailored to the situation of institutions can be suggested.

17.3) Summary of recommendation statements

1. In critically ill patients requiring CKRT, a specialized or multidisciplinary team approach may improve the filter lifespan and reduce the downtime of CKRT.
2. There is a lack of evidence that a specialized or multidisciplinary team approach reduces the risk of mortality of critically ill patients requiring CKRT.
3. The benefit of a specialized or multidisciplinary team approach in critically ill patients requiring CKRT should be further evaluated in prospective RCTs.
4. Considering the possible intangible benefits of a specialized or multidisciplinary team approach, it is possible to suggest a specialized team approach based on cost-effectiveness considerations.

Strength of recommendation: Expert consensus

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17.4) Rationale

CKRT has played an important role in the treatment of critically ill patients. Nevertheless, the survival outcomes of critically ill patients requiring CKRT remain low. Appropriate anticoagulation therapy and filter changes, maintenance of dose, and surveillance for electrolyte imbalances are thought to help improve survival rate in these patients [267]. With this background, some institutions in Korea have started CKRT specialized team approach. While specialized team approach varies from institution to institution, setting up teams including healthcare workers involved in CKRT, organizing training programs, establishing protocols and quality control were similar.

In this guideline, we reviewed six retrospective cohort studies from single centers to examine whether specialized team approach in critically ill patients initiating CKRT is beneficial for patient outcomes including survival rate, filter lifespan, etc. For CKRT specialized team approach, Korean hospitals have made teams of clinicians, mainly from division of nephrology, pediatric nephrology, and critical care, and nursing staff to run CKRT machine. Nursing staff included in the CKRT specialized team in Korea were solely responsible for CKRT operations. In other countries, even cardiologists, cardiac surgeons, nutritionists, pharmacists, bioinformatics specialists, and CKRT machine technicians were included in the form of multidisciplinary team.

A single-center Korean study of 551 adult patients undergoing CKRT for AKI reported a significantly lower risk of 28-day mortality, significantly less downtime and fewer filters after CKRT specialized team approach [267]. Additional analysis of 1:1 matched 334 adult patients initiating CKRT for AKI at the same institution similarly reported a lower risk of 28- and 90-day mortality in patients after the initiation of a CKRT specialized team approach. Although this study did not show a benefit in increased filter lifespan, downtime was significantly reduced in patients following CKRT specialized team approach [268]. However, in a study of pediatric patients undergoing CKRT at the same institution, there was no clinical improvement following the implementation of a specialized CKRT team approach [269].

In another single-center study in South Korea of 1,104 adult patients undergoing CKRT, patients with a CKRT specialist team had significantly longer filter lifespan and reduced downtime. The CKRT specialized team approach was also associated with a reduced risk of death, but did not lower the risk of death during CKRT [270].

A US study of 1185 adult patients on CKRT before and after a phased implementation of CKRT quality improvement based on the multidisciplinary team approach found increased filter lifespan and fewer alarms from CKRT machines after quality improvement [271]. However, a single-center Japanese study comparing 540 adults undergoing CKRT before and after a multidisciplinary team did not show a significant clinical benefit [272].

To date, no randomized trials of the CKRT specialized or multidisciplinary team approach have been conducted. In addition, the retrospective studies that have been conducted so far are all single-center studies, and the elements of the CKRT team approach and related protocols vary by institution, and the characteristics of the patients included were heterogeneous. Therefore, further studies are required to clarify the benefit of CKRT specialized or multidisciplinary team approach.

On the other hand, in addition to the tangible results described above, it is possible to expect additional results such as efficient operation of CKRT devices and reduction of the workload of medical staff in charge of critically ill patients. However, since the CKRT specialized or multidisciplinary team approach requires additional budgets such as recruitment of personnel, it is thought that a strategy tailored to the situation of each medical institution is necessary.

17.5) Considerations

17.5.1) Benefits and harms

For critically ill patients requiring CKRT, a CKRT specialized/multidisciplinary team approach is unlikely to harm these patients, as it is likely to improve filter lifespan and reduce downtime.

17.5.2) Patients' values and preferences

From the patient's perspective, the CKRT specialized/multidisciplinary team approach is associated with continuity of critical care due to increased filter lifespan and reduced downtime, which does not conflict with patient values and preferences.

17.5.3) Obstacles and solutions

The CKRT specialized/multidisciplinary team approach implemented in the current studies, which requires the training of dedicated personnel and ongoing quality control, may lead to increased healthcare costs. Each institution should develop methods tailored to its resources and capabilities.

17.5.4) Resources

The CKRT specialized/multidisciplinary team approach requires the training of dedicated personnel and the ongoing quality control, and additional cost cannot be ignored. However, as observed in some studies above, increased filter lifespan may have the effect of reducing the workload and costs per patient. Therefore, it seems necessary to consider cost-effectiveness of the CKRT specialized team approach.

DISCUSSION

This is the first evidence-based clinical practice guideline for CKRT in Korea, developed by a multidisciplinary team of nephrologists, intensivists, and methodology experts through the collaboration of the Korean Society of Nephrology and the Korean Society of Critical Care Nephrology. Its primary significance lies in presenting standardized recommendations for the application and prescription of CKRT based on the latest research, reflecting the unique aspects of the Korean healthcare environment and aiming to improve patient outcomes and reduce complications. This guideline provided 17 specific recommendations covering initiation, dose, modality, dialysate, ultrafiltration, anticoagulation, nutrition, and special populations (ECMO, brain injury, pediatrics, liver transplantation). Furthermore, this guideline emphasizes the importance of nephrology consultation and multidisciplinary team-based management for effective application in clinical practice. To support implementation, we propose an integrated CKRT care model summarizing expected benefits in real-world practice (**Fig. 4**).

This guideline establishes three core principles for contemporary CKRT practice. The first is a paradigm shift from standardized protocols to patient-tailored therapeutic strategies. This principle is evident in key recommendations that move beyond the dichotomous 'early

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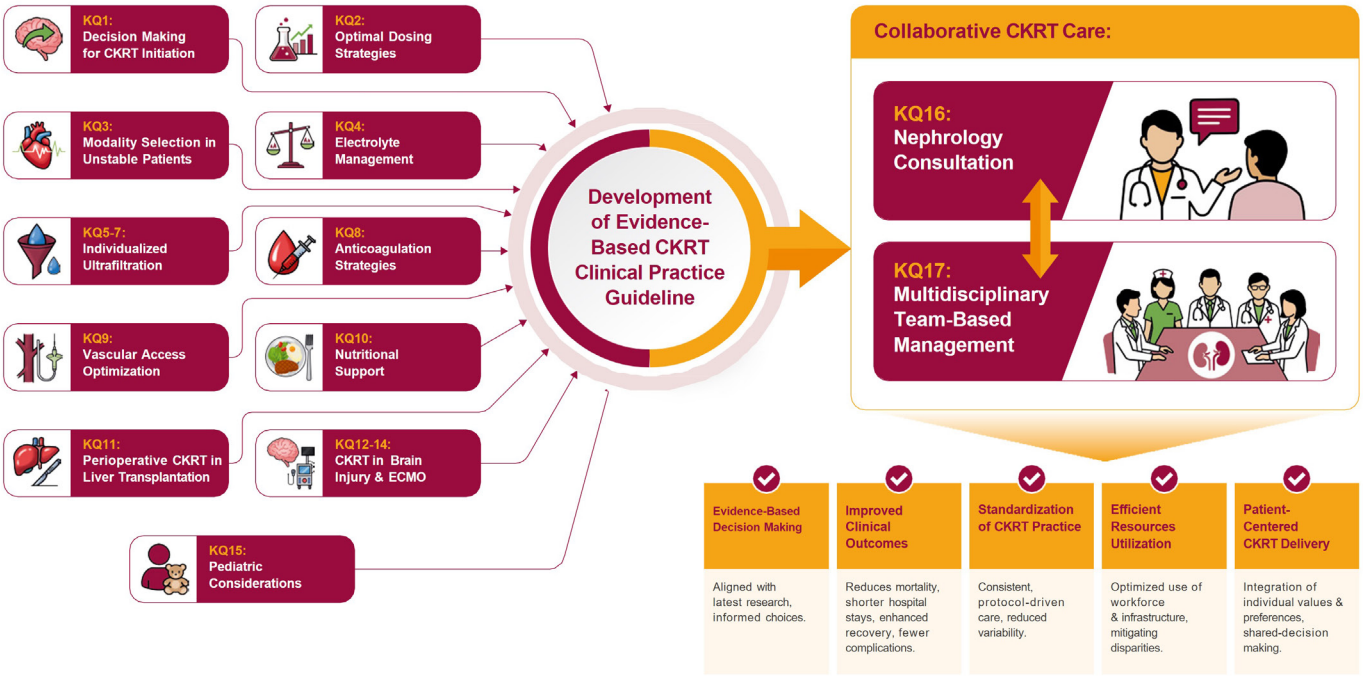

Fig. 4. Integrated CKRT care model highlighting nephrology consultation and multidisciplinary team-based management (Key Questions 1–17).
Conceptual framework summarizing the expected impact of the 2025 Evidence-Based Clinical Practice Guideline for CKRT. Key question-driven recommendations support decision making across initiation, dosing, modality selection, anticoagulation, vascular access, special clinical situations, and pediatric care. Central to implementation, KQ16 (nephrology consultation) and KQ17 (multidisciplinary team-based management) emphasize collaborative CKRT care. Expected benefits include: improved clinical outcomes, standardization of CKRT practice, efficient resource utilization, and patient-centered therapy aligned with individual values and shared decision-making.
CKRT, continuous kidney replacement therapy; ECMO, extracorporeal membrane oxygenation; KQ#, Key Question #; TPL, transplantation.

versus late' debate on CKRT initiation, instead advocating for a decision based on a holistic assessment of the patient's clinical status, including bleeding and infection risks. Similarly, the guideline advises against the routine use of high-dose therapy, underscoring the need to titrate the dose according to patient severity and metabolic demands. The choice of RRT modality is also framed contextually, with a conditional recommendation for CKRT in the specific subpopulation of hemodynamically unstable patients.

The second core principle is a strong emphasis on proactive strategies for complication prevention and quality improvement. This is highlighted by the strong recommendation for ultrasound-guided hemodialysis catheter insertion to enhance procedural safety and success rates. Furthermore, the guideline proposes practical measures to mitigate common in-treatment complications, such as using phosphate-containing dialysates to prevent hypophosphatemia and ensuring adequate nutritional support. Notably, the recommendation to consider nafamostat for anticoagulation provides pragmatic, context-specific evidence for the Korean healthcare environment where regional citrate anticoagulation has limited accessibility.

Finally, the guideline addresses the complexities of managing special patient populations and the value of collaborative care. For cohorts such as patients receiving ECMO, those with acute brain injury, and pediatric populations, it acknowledges that the current evidence is often limited; consequently, most recommendations for these groups are guided by expert consensus, highlighting a critical area for future clinical research. In conjunction, the guideline underscores that a multidisciplinary team approach can significantly improve

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filter lifespan and reduce treatment downtime, emphasizing the importance of establishing institutional protocols and collaborative practice models to optimize patient care.

Despite the rigorous methodology applied in developing this guideline, several limitations must be acknowledged. First, there remain substantial evidence gaps: many recommendations, particularly those concerning pediatrics, ECMO, and nutrition, are supported primarily by low-quality evidence or expert consensus. Second, there is a lack of RCTs in Korean populations; most of the evidence is drawn from international studies, and thus generalizability may be constrained by differences in practice patterns and healthcare infrastructure. Third, CKRT is a rapidly evolving field, with continuous developments in technology, anticoagulation strategies, and dialysate solutions, meaning that some recommendations may require timely revision. Lastly, resource variability across institutions may affect implementation, especially in smaller centers with limited personnel or equipment, requiring flexible adaptation of the recommendations.

This guideline also identifies critical knowledge gaps that should inform future investigations. Key priorities include defining the optimal timing and discontinuation criteria for CKRT in different subgroups of AKI, conducting randomized studies in Korean populations to evaluate anticoagulation strategies, dialysate composition, and fluid management protocols, and performing dedicated trials in pediatric and ECMO populations. Additionally, cost-effectiveness analyses are needed to guide healthcare policy, and studies examining the outcomes of multidisciplinary team models in Korean ICUs are warranted.

The 2025 Korean Society of Nephrology and Critical Care Nephrology guideline represents a significant milestone in standardizing CKRT practice in the Korean clinical setting. By providing balanced, evidence-based, and context-specific recommendations, this guideline aims to improve consistency of care and clinical outcomes while acknowledging real-world variations in resources and institutional practice. It seeks to standardize CKRT prescription and monitoring, reduce preventable complications, support renal recovery, and promote more efficient use of healthcare resources, while still allowing individualized treatment decisions based on patient condition and multidisciplinary judgment.

We expect that this guideline will be widely utilized to enhance the quality of care for critically ill patients with AKI, serve as an educational resource for healthcare professionals, and support shared decision-making when appropriate. We also anticipate that the clinical questions and evidence gaps identified here will guide future research, particularly in high-risk subgroups where current evidence remains limited.

To ensure ongoing relevance and practicality, updates will be performed at least every five or ten years—or earlier if pivotal new evidence emerges—to incorporate advances in research, domestic data, and evolving treatment strategies. Through continuous evaluation and refinement, we aim to sustain the clinical applicability and long-term impact of this guideline in improving outcomes for patients requiring CKRT.

SUPPLEMENTARY MATERIALS

Supplementary Data 1
Search terms (KQ1–KQ17)

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Supplementary Data 2
External reviewers & affiliations

Supplementary Table 1
Evidence summary tables

Supplementary Table 2
GRADE summary of findings

Supplementary Fig. 1
PRISMA flow diagram.

Supplementary Fig. 2
Risk of bias assessment for randomized controlled trials (RoB) and non-randomized studies (RoBANS).

Supplementary Fig. 3
Forest plots (KQ1–KQ17).

REFERENCES

1. Teixeira JP, Hiremath S, Kabli AO, Rewa OG, Clark EG. Continuous kidney replacement therapies: core curriculum 2025. *Am J Kidney Dis* 2025;85:767-786. PUBMED | CROSSREF
2. Chaïbi K, Dreyfuss D, Gaudry S. Debate: Intermittent hemodialysis versus continuous kidney replacement therapy in the critically ill patient: the choice should be evidence based. *Clin J Am Soc Nephrol* 2023;18:661-667. PUBMED | CROSSREF
3. Macedo E, Mehta RL. Continuous dialysis therapies: core curriculum 2016. *Am J Kidney Dis* 2016;68:645-657. PUBMED | CROSSREF
4. Park S, Lee S, Jo HA, et al. Epidemiology of continuous renal replacement therapy in Korea: results from the National Health Insurance Service claims database from 2005 to 2016. *Kidney Res Clin Pract* 2018;37:119-129. PUBMED | CROSSREF
5. Tain YL, Kuo HC, Hsu CN. Changing trends in dialysis modalities utilization and mortality in children, adolescents and young adults with acute kidney injury, 2010-2017. *Sci Rep* 2021;11:11887. PUBMED | CROSSREF
6. Bouchard J, Mehta RL. Timing of kidney support therapy in acute kidney injury: what are we waiting for? *Am J Kidney Dis* 2022;79:417-426. PUBMED | CROSSREF
7. Jörres A, John S, Lewington A, et al. A European Renal Best Practice (ERBP) position statement on the Kidney Disease Improving Global Outcomes (KDIGO) Clinical Practice Guidelines on Acute Kidney Injury: part 2: renal replacement therapy. *Nephrol Dial Transplant* 2013;28:2940-2945. PUBMED | CROSSREF
8. Palevsky PM, Liu KD, Brophy PD, et al. KDOQI US commentary on the 2012 KDIGO clinical practice guideline for acute kidney injury. *Am J Kidney Dis* 2013;61:649-672. PUBMED | CROSSREF
9. Vinsonneau C, Allain-Launay E, Blayau C, et al. Renal replacement therapy in adult and pediatric intensive care : recommendations by an expert panel from the French Intensive Care Society (SRLF) with the French Society of Anesthesia Intensive Care (SFAR) French Group for Pediatric Intensive Care Emergencies (GFRUP) the French Dialysis Society (SFD). *Ann Intensive Care* 2015;5:58. PUBMED | CROSSREF
10. Doi K, Nishida O, Shigematsu T, et al. The Japanese clinical practice guideline for acute kidney injury 2016. *Clin Exp Nephrol* 2018;22:985-1045. PUBMED | CROSSREF
11. National Institute for Health and Care Excellence (NICE). Clinical Guidelines. Acute kidney injury: prevention, detection and management. London: NICE; 2023.
12. Srisawat N, Laoveeravat P, Limphunudom P, et al. The effect of early renal replacement therapy guided by plasma neutrophil gelatinase associated lipocalin on outcome of acute kidney injury: a feasibility study. *J Crit Care* 2018;43:36-41. PUBMED | CROSSREF

13. STARRT-AKI Investigators; Canadian Critical Care Trials Group; Australian and New Zealand Intensive Care Society Clinical Trials Group Timing of initiation of renal-replacement therapy in acute kidney injury. *N Engl J Med* 2020;383:240-251. PUBMED | CROSSREF

14. Barbar SD, Clere-Jehl R, Bourredjem A, et al. Timing of renal-replacement therapy in patients with acute kidney injury and sepsis. *N Engl J Med* 2018;379:1431-1442. PUBMED | CROSSREF

15. Combes A, Bréchot N, Amour J, et al. Early high-volume hemofiltration versus standard care for post-cardiac surgery shock. The HEROICS study. *Am J Respir Crit Care Med* 2015;192:1179-1190. PUBMED | CROSSREF

16. Gaudry S, Hajage D, Martin-Lefevre L, et al. Comparison of two delayed strategies for renal replacement therapy initiation for severe acute kidney injury (AKIKI 2): a multicentre, open-label, randomised, controlled trial. *Lancet* 2021;397:1293-1300. PUBMED | CROSSREF

17. Gaudry S, Hajage D, Schortgen F, et al. Initiation strategies for renal-replacement therapy in the intensive care unit. *N Engl J Med* 2016;375:122-133. PUBMED | CROSSREF

18. Geri G, Grimaldi D, Seguin T, et al. Hemodynamic efficiency of hemodialysis treatment with high cut-off membrane during the early period of post-resuscitation shock: the HYPERDIA trial. *Resuscitation* 2019;140:170-177. PUBMED | CROSSREF

19. Jamale TE, Hase NK, Kulkarni M, et al. Earlier-start versus usual-start dialysis in patients with community-acquired acute kidney injury: a randomized controlled trial. *Am J Kidney Dis* 2013;62:1116-1121. PUBMED | CROSSREF

20. Lumlertgul N, Peerapornratana S, Trakarnvanich T, et al. Early versus standard initiation of renal replacement therapy in furosemide stress test non-responsive acute kidney injury patients (the FST trial). *Crit Care* 2018;22:101. PUBMED | CROSSREF

21. Wald R, Adhikari NK, Smith OM, et al. Comparison of standard and accelerated initiation of renal replacement therapy in acute kidney injury. *Kidney Int* 2015;88:897-904. PUBMED | CROSSREF

22. Zarbock A, Kellum JA, Schmidt C, et al. Effect of early vs delayed initiation of renal replacement therapy on mortality in critically ill patients with acute kidney injury: the ELAIN randomized clinical trial. *JAMA* 2016;315:2190-2199. PUBMED | CROSSREF

23. RENAL Replacement Therapy Study Investigators, Bellomo R, Cass A, et al. Intensity of continuous renal-replacement therapy in critically ill patients. *N Engl J Med* 2009;361:1627-1638. PUBMED | CROSSREF

24. VA/NIH Acute Renal Failure Trial Network, Palevsky PM, Zhang JH, et al. Intensity of renal support in critically ill patients with acute kidney injury. *N Engl J Med* 2008;359:7-20. PUBMED | CROSSREF

25. Heering P, Morgera S, Schmitz FJ, et al. Cytokine removal and cardiovascular hemodynamics in septic patients with continuous venovenous hemofiltration. *Intensive Care Med* 1997;23:288-296. PUBMED | CROSSREF

26. Kellum JA, Johnson JP, Kramer D, Palevsky P, Brady JJ, Pinsky MR. Diffusive vs. convective therapy: effects on mediators of inflammation in patient with severe systemic inflammatory response syndrome. *Crit Care Med* 1998;26:1995-2000. PUBMED | CROSSREF

27. Morgera S, Slowinski T, Melzer C, et al. Renal replacement therapy with high-cutoff hemofilters: impact of convection and diffusion on cytokine clearances and protein status. *Am J Kidney Dis* 2004;43:444-453. PUBMED | CROSSREF

28. Zhang P, Yang Y, Lv R, Zhang Y, Xie W, Chen J. Effect of the intensity of continuous renal replacement therapy in patients with sepsis and acute kidney injury: a single-center randomized clinical trial. *Nephrol Dial Transplant* 2012;27:967-973. PUBMED | CROSSREF

29. Park JT, Lee H, Kee YK, et al. High-dose versus conventional-dose continuous venovenous hemodiafiltration and patient and kidney survival and cytokine removal in sepsis-associated acute kidney injury: a randomized controlled trial. *Am J Kidney Dis* 2016;68:599-608. PUBMED | CROSSREF

30. Chung KK, Coates EC, Smith DJ Jr, et al. High-volume hemofiltration in adult burn patients with septic shock and acute kidney injury: a multicenter randomized controlled trial. *Crit Care* 2017;21:289. PUBMED | CROSSREF

31. Joannes-Boyau O, Honoré PM, Perez P, et al. High-volume versus standard-volume haemofiltration for septic shock patients with acute kidney injury (IVOIRE study): a multicentre randomized controlled trial. *Intensive Care Med* 2013;39:1535-1546. PUBMED | CROSSREF

32. Vesconi S, Cruz DN, Fumagalli R, et al. Delivered dose of renal replacement therapy and mortality in critically ill patients with acute kidney injury. *Crit Care* 2009;13:R57. PUBMED | CROSSREF

33. Venkataraman R, Kellum JA, Palevsky P. Dosing patterns for continuous renal replacement therapy at a large academic medical center in the United States. *J Crit Care* 2002;17:246-250. PUBMED | CROSSREF

34. Piccinni P, Dan M, Barbacini S, et al. Early isovolaemic haemofiltration in oliguric patients with septic shock. *Intensive Care Med* 2006;32:80-86. PUBMED | CROSSREF

35. Kielstein JT, Eugbers C, Bode-Boeger SM, et al. Dosing of daptomycin in intensive care unit patients with acute kidney injury undergoing extended dialysis--a pharmacokinetic study. *Nephrol Dial Transplant* 2010;25:1537-1541. PUBMED | CROSSREF

36. Kielstein JT, Lorenzen J, Kaever V, et al. Risk of underdosing of ampicillin/sulbactam in patients with acute kidney injury undergoing extended daily dialysis--a single case. *Nephrol Dial Transplant* 2009;24:2283-2285. PUBMED | CROSSREF

37. An JN, Kim SG, Song YR. When and why to start continuous renal replacement therapy in critically ill patients with acute kidney injury. *Kidney Res Clin Pract* 2021;40:566-577. PUBMED | CROSSREF

38. Peerapornratana S, Manrique-Caballero CL, Gómez H, Kellum JA. Acute kidney injury from sepsis: current concepts, epidemiology, pathophysiology, prevention and treatment. *Kidney Int* 2019;96:1083-1099. PUBMED | CROSSREF

39. Shime N, Nakada TA, Yatabe T, et al. The Japanese Clinical Practice Guidelines for Management of Sepsis and Septic Shock 2024. *J Intensive Care* 2025;13:15. PUBMED | CROSSREF

40. Palevsky PM. Debate: Intermittent hemodialysis versus continuous kidney replacement therapy in the critically ill patient: moderator commentary. *Clin J Am Soc Nephrol* 2023;18:644-646. PUBMED | CROSSREF

41. Abe M, Maruyama N, Matsumoto S, et al. Comparison of sustained hemodiafiltration with acetate-free dialysate and continuous venovenous hemodiafiltration for the treatment of critically ill patients with acute kidney injury. *Int J Nephrol* 2011;2011:432094. PUBMED | CROSSREF

42. Abe M, Okada K, Suzuki M, et al. Comparison of sustained hemodiafiltration with continuous venovenous hemodiafiltration for the treatment of critically ill patients with acute kidney injury. *Artif Organs* 2010;34:331-338. PUBMED | CROSSREF

43. Augustine JJ, Sandy D, Seifert TH, Paganini EP. A randomized controlled trial comparing intermittent with continuous dialysis in patients with ARF. *Am J Kidney Dis* 2004;44:1000-1007. PUBMED | CROSSREF

44. Gasparović V, Filipović-Grcić I, Merkler M, Pisl Z. Continuous renal replacement therapy (CRRT) or intermittent hemodialysis (IHD)--what is the procedure of choice in critically ill patients? *Ren Fail* 2003;25:855-862. PUBMED | CROSSREF

45. Badawy SSI, Hassan AR, Samir EM. A prospective randomized comparative pilot trial on extended daily dialysis versus continuous venovenous hemodiafiltration in acute kidney injury after cardiac surgery. *Egypt J Cardiothorac Anesth* 2013;7:69-73. CROSSREF

46. Kielstein JT, Kretschmer U, Ernst T, et al. Efficacy and cardiovascular tolerability of extended dialysis in critically ill patients: a randomized controlled study. *Am J Kidney Dis* 2004;43:342-349. PUBMED | CROSSREF

47. Lins RL, Elseviers MM, Van der Niepen P, et al. Intermittent versus continuous renal replacement therapy for acute kidney injury patients admitted to the intensive care unit: results of a randomized clinical trial. *Nephrol Dial Transplant* 2009;24:512-518. PUBMED | CROSSREF

48. Mehta RL, McDonald B, Gabbai FB, et al. A randomized clinical trial of continuous versus intermittent dialysis for acute renal failure. *Kidney Int* 2001;60:1154-1163. PUBMED | CROSSREF

49. Schefold JC, von Haehling S, Pschowski R, et al. The effect of continuous versus intermittent renal replacement therapy on the outcome of critically ill patients with acute renal failure (CONVINT): a prospective randomized controlled trial. *Crit Care* 2014;18:R11. PUBMED | CROSSREF

50. Schwenger V, Weigand MA, Hoffmann O, et al. Sustained low efficiency dialysis using a single-pass batch system in acute kidney injury - a randomized interventional trial: the REnal Replacement Therapy Study in Intensive Care Unit PatiEnts. *Crit Care* 2012;16:R140. PUBMED | CROSSREF

51. Uehlinger DE, Jakob SM, Ferrari P, et al. Comparison of continuous and intermittent renal replacement therapy for acute renal failure. *Nephrol Dial Transplant* 2005;20:1630-1637. PUBMED | CROSSREF

52. Vinsonneau C, Camus C, Combes A, et al. Continuous venovenous haemodiafiltration versus intermittent haemodialysis for acute renal failure in patients with multiple-organ dysfunction syndrome: a multicentre randomised trial. *Lancet* 2006;368:379-385. PUBMED | CROSSREF

53. Gaudry S, Grolleau F, Barbar S, et al. Continuous renal replacement therapy versus intermittent hemodialysis as first modality for renal replacement therapy in severe acute kidney injury: a secondary analysis of AKIKI and IDEAL-ICU studies. *Crit Care* 2022;26:93. PUBMED | CROSSREF

54. Thompson Bastin ML, Adams PM, Nerusu S, Morris PE, Mayer KP, Neyra JA. Association of phosphate containing solutions with incident hypophosphatemia in critically ill patients requiring continuous renal replacement therapy. *Blood Purif* 2022;51:122-129. PUBMED | CROSSREF

55. Broman M, Carlsson O, Friberg H, Wieslander A, Godaly G. Phosphate-containing dialysis solution prevents hypophosphatemia during continuous renal replacement therapy. *Acta Anaesthesiol Scand* 2011;55:39-45. PUBMED | CROSSREF

56. Godaly G, Carlsson O, Broman M. Phoxilium® reduces hypophosphataemia and magnesium supplementation during continuous renal replacement therapy. *Clin Kidney J* 2016;9:205-210. PUBMED | CROSSREF

57. Crowley KE, DeGrado JR, Charytan DM. Serum glucose and phosphorus concentrations during continuous renal replacement therapy using commercial replacement solutions with or without phosphorus. *Hemodial Int* 2020;24:330-334. PUBMED | CROSSREF

58. Cho A, Lee YK, Park HC. Impact of electrolyte-rich dialysate during continuous renal replacement therapy on serum phosphate and potassium in ICU patients. *PLoS One* 2020;15:e0238867. PUBMED | CROSSREF

59. Morabito S, Pistolesi V, Tritapepe L, et al. Continuous venovenous hemodiafiltration with a low citrate dose regional anticoagulation protocol and a phosphate-containing solution: effects on acid-base status and phosphate supplementation needs. *BMC Nephrol* 2013;14:232. PUBMED | CROSSREF

60. Nalesso F, Garzotto F, Cattarin L, Innico G, Gobbi L, Calò LA. Impact of different hemodiafiltration solutions on ionemia in long-term CRRT. *Int J Artif Organs* 2021;44:807-815. PUBMED | CROSSREF

61. Chua HR, Baldwin I, Ho L, Collins A, Allsep H, Bellomo R. Biochemical effects of phosphate-containing replacement fluid for continuous venovenous hemofiltration. *Blood Purif* 2012;34:306-312. PUBMED | CROSSREF

62. Chua HR, Schneider AG, Baldwin I, Collins A, Ho L, Bellomo R. Phoxilium vs Hemosol-B0 for continuous renal replacement therapy in acute kidney injury. *J Crit Care* 2013;28:884.e7-884.e14. PUBMED | CROSSREF

63. Song YH, Seo EH, Yoo YS, Jo YI. Phosphate supplementation for hypophosphatemia during continuous renal replacement therapy in adults. *Ren Fail* 2019;41:72-79. PUBMED | CROSSREF

64. Besnard N, Serveaux M, Machado S, et al. Electrolytes-enriched hemodiafiltration solutions for continuous renal replacement therapy in acute kidney injury: a crossover study. *Blood Purif* 2016;42:18-26. PUBMED | CROSSREF

65. Thompson Bastin ML, Stromberg AJ, Nerusu SN, et al. Association of phosphate-containing versus phosphate-free solutions on ventilator days in patients requiring continuous kidney replacement therapy. *Clin J Am Soc Nephrol* 2022;17:634-642. PUBMED | CROSSREF

66. Baeg SI, Jeon J, Kang D, et al. Impact of protocolized fluid management on electrolyte stability in patients undergoing continuous renal replacement therapy. *Front Med (Lausanne)* 2022;9:915072. PUBMED | CROSSREF

67. Prowle JR, Echeverri JE, Ligabo EV, Ronco C, Bellomo R. Fluid balance and acute kidney injury. *Nat Rev Nephrol* 2010;6:107-115. PUBMED | CROSSREF

68. Malbrain MLNG, Van Regenmortel N, Saugel B, et al. Principles of fluid management and stewardship in septic shock: it is time to consider the four D's and the four phases of fluid therapy. *Ann Intensive Care* 2018;8:66. PUBMED | CROSSREF

69. Murugan R, Bellomo R, Palevsky PM, Kellum JA. Ultrafiltration in critically ill patients treated with kidney replacement therapy. *Nat Rev Nephrol* 2021;17:262-276. PUBMED | CROSSREF

70. Murugan R, Kerti SJ, Chang CH, et al. Association of net ultrafiltration rate with mortality among critically ill adults with acute kidney injury receiving continuous venovenous hemodiafiltration: a secondary analysis of the Randomized Evaluation of Normal vs Augmented Level (RENAL) of Renal Replacement Therapy trial. *JAMA Netw Open* 2019;2:e195418. PUBMED | CROSSREF

71. Naorungroj T, Neto AS, Zwakman-Hessels L, et al. Early net ultrafiltration rate and mortality in critically ill patients receiving continuous renal replacement therapy. *Nephrol Dial Transplant* 2021;36:1112-1119. PUBMED | CROSSREF

72. Naorungroj T, Neto AS, Zwakman-Hessels L, et al. Mediators of the impact of hourly net ultrafiltration rate on mortality in critically ill patients receiving continuous renal replacement therapy. *Crit Care Med* 2020;48:e934-e942. PUBMED | CROSSREF

73. Murugan R, Kerti SJ, Chang CH, et al. Association between Net ultrafiltration rate and renal recovery among critically ill adults with acute kidney injury receiving continuous renal replacement therapy: an observational cohort study. *Blood Purif* 2022;51:397-409. PUBMED | CROSSREF

74. Jhee JH, Lee HA, Kim S, et al. The interactive effects of input and output on managing fluid balance in patients with acute kidney injury requiring continuous renal replacement therapy. *Crit Care* 2019;23:329. PUBMED | CROSSREF

75. Murugan R, Balakumar V, Kerti SJ, et al. Net ultrafiltration intensity and mortality in critically ill patients with fluid overload. *Crit Care* 2018;22:223. PUBMED | CROSSREF

76. Naorungroj T, Neto AS, Zwakman-Hessels L, Yanase F, Eastwood G, Bellomo R. Hourly fluid balance in patients receiving continuous renal replacement therapy. *Blood Purif* 2020;49:93-101. PUBMED | CROSSREF

77. Uusalo P, Hellman T, Löyttyniemi E, Peltoniemi J, Järvisalo MJ. Early restrictive fluid balance is associated with lower hospital mortality independent of acute disease severity in critically ill patients on CRRT. *Sci Rep* 2021;11:18216. PUBMED | CROSSREF

78. An JN, Oh HJ, Oh S, et al. Bioimpedance-guided fluid removal in continuous KRT: the VENUS randomized clinical trial. *Clin J Am Soc Nephrol* 2024;19:1527-1536. PUBMED | CROSSREF

79. Badawy SS, Fahmy A. Efficacy and cardiovascular tolerability of continuous veno-venous hemodiafiltration in acute decompensated heart failure: a randomized comparative study. *J Crit Care* 2012;27:106.e7-106.e13. PUBMED | CROSSREF

80. Bart BA, Boyle A, Bank AJ, et al. Ultrafiltration versus usual care for hospitalized patients with heart failure: the Relief for Acutely Fluid-Overloaded Patients With Decompensated Congestive Heart Failure (RAPID-CHF) trial. *J Am Coll Cardiol* 2005;46:2043-2046. PUBMED | CROSSREF

81. Costanzo MR, Guglin ME, Saltzberg MT, et al. Ultrafiltration versus intravenous diuretics for patients hospitalized for acute decompensated heart failure. *J Am Coll Cardiol* 2007;49:675-683. PUBMED | CROSSREF

82. Giglioli C, Landi D, Cecchi E, et al. Effects of ULTRAfiltration vs. DIureticS on clinical, biohumoral and haemodynamic variables in patients with deCOmpensated heart failure: the ULTRADISCO study. *Eur J Heart Fail* 2011;13:337-346. PUBMED | CROSSREF

83. Rogers HL, Marshall J, Bock J, et al. A randomized, controlled trial of the renal effects of ultrafiltration as compared to furosemide in patients with acute decompensated heart failure. *J Card Fail* 2008;14:1-5. PUBMED | CROSSREF

84. Bart BA, Goldsmith SR, Lee KL, et al. Ultrafiltration in decompensated heart failure with cardiorenal syndrome. *N Engl J Med* 2012;367:2296-2304. PUBMED | CROSSREF

85. Grodin JL, Carter S, Bart BA, Goldsmith SR, Drazner MH, Tang WHW. Direct comparison of ultrafiltration to pharmacological decongestion in heart failure: a per-protocol analysis of CARRESS-HF. *Eur J Heart Fail* 2018;20:1148-1156. PUBMED | CROSSREF

86. McDonagh TA, Metra M, Adamo M, et al. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. *Eur Heart J* 2021;42:3599-3726. PUBMED | CROSSREF

87. Costanzo MR, Negoianu D, Jaski BE, et al. Aquapheresis versus intravenous diuretics and hospitalizations for heart failure. *JACC Heart Fail* 2016;4:95-105. PUBMED | CROSSREF

88. Heidenreich PA, Bozkurt B, Aguilar D, et al. 2022 AHA/ACC/HFSA guideline for the management of heart failure: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation* 2022;145:e895-e1032. PUBMED | CROSSREF

89. Hu J, Wan Q, Zhang Y, et al. Efficacy and safety of early ultrafiltration in patients with acute decompensated heart failure with volume overload: a prospective, randomized, controlled clinical trial. *BMC Cardiovasc Disord* 2020;20:447. PUBMED | CROSSREF

90. Hanna MA, Tang WH, Teo BW, et al. Extracorporeal ultrafiltration vs. conventional diuretic therapy in advanced decompensated heart failure. *Congest Heart Fail* 2012;18:54-63. PUBMED | CROSSREF

91. van der Voort PH, Boerma EC, Koopmans M, et al. Furosemide does not improve renal recovery after hemofiltration for acute renal failure in critically ill patients: a double blind randomized controlled trial. *Crit Care Med* 2009;37:533-538. PUBMED | CROSSREF

92. Jeon J, Kim DH, Baeg SI, et al. Association between diuretics and successful discontinuation of continuous renal replacement therapy in critically ill patients with acute kidney injury. *Crit Care* 2018;22:255. PUBMED | CROSSREF

93. Raurich JM, Llompart-Pou JA, Novo MA, Talavera C, Ferreruela M, Ayestarán I. Successful weaning from continuous renal replacement therapy. Associated risk factors. *J Crit Care* 2018;45:144-148. PUBMED | CROSSREF

94. Uchino S, Bellomo R, Morimatsu H, et al. Discontinuation of continuous renal replacement therapy: a post hoc analysis of a prospective multicenter observational study. *Crit Care Med* 2009;37:2576-2582. PUBMED | CROSSREF

95. Baeg SI, Jeon J, Yoo H, et al. A scoring model with simple clinical parameters to predict successful discontinuation of continuous renal replacement therapy. *Blood Purif* 2021;50:779-789. PUBMED | CROSSREF

96. Tourneur JM, Weissbrich C, Putensen C, Hilbert T. Feasibility of a protocol to wean patients from continuous renal replacement therapy: a retrospective pilot observation. *J Crit Care* 2019;53:236-243. PUBMED | CROSSREF

97. Katayama S, Uchino S, Uji M, et al. Factors predicting successful discontinuation of continuous renal replacement therapy. *Anaesth Intensive Care* 2016;44:453-457. PUBMED | CROSSREF

98. Kim CS, Bae EH, Ma SK, Kim SW. A prospective observational study on the predictive value of serum cystatin C for successful weaning from continuous renal replacement therapy. *Kidney Blood Press Res* 2018;43:872-881. PUBMED | CROSSREF

99. Chen X, Chen Z, Wei T, Li P, Zhang L, Fu P. The effect of serum neutrophil gelatinase-associated lipocalin on the discontinuation of continuous renal replacement therapy in critically ill patients with acute kidney injury. *Blood Purif* 2019;48:10-17. PUBMED | CROSSREF

100. Yoshida T, Matsuura R, Komaru Y, et al. Kinetic estimated glomerular filtration rate as a predictor of successful continuous renal replacement therapy discontinuation. *Nephrology (Carlton)* 2019;24:287-293. PUBMED | CROSSREF

101. Section 5: Dialysis interventions for treatment of AKI. *Kidney Int Suppl (2011)* 2012;2:89-115. PUBMED | CROSSREF

102. Uchiba M, Okajima K, Abe H, Okabe H, Takatsuki K. Effect of nafamostat mesilate, a synthetic protease inhibitor, on tissue factor-factor VIIa complex activity. *Thromb Res* 1994;74:155-161. PUBMED | CROSSREF

103. Park II, Choi MJ, Yoon JW, et al. Saline versus nafamostat mesilate anticoagulation for continuous veno-venous hemofiltration (CVVH) in patients at high risk of bleeding: a prospective study. *Korean J Nephrol* 2009;28:205-210.

104. Lee YK, Lee HW, Choi KH, Kim BS. Ability of nafamostat mesilate to prolong filter patency during continuous renal replacement therapy in patients at high risk of bleeding: a randomized controlled study. *PLoS One* 2014;9:e108737. PUBMED | CROSSREF

105. Choi JY, Kang YJ, Jang HM, et al. Nafamostat mesilate as an anticoagulant during continuous renal replacement therapy in patients with high bleeding risk: a randomized clinical trial. *Medicine (Baltimore)* 2015;94:e2392. PUBMED | CROSSREF

106. Lin Y, Shao Y, Liu Y, et al. Efficacy and safety of nafamostat mesilate anticoagulation in blood purification treatment of critically ill patients: a systematic review and meta-analysis. *Ren Fail* 2022;44:1263-1279. PUBMED | CROSSREF

107. Baek NN, Jang HR, Huh W, et al. The role of nafamostat mesylate in continuous renal replacement therapy among patients at high risk of bleeding. *Ren Fail* 2012;34:279-285. PUBMED | CROSSREF

108. Hwang SD, Hyun YK, Moon SJ, Lee SC, Yoon SY. Nafamostat mesilate for anticoagulation in continuous renal replacement therapy. *Int J Artif Organs* 2013;36:208-216. PUBMED | CROSSREF

109. Kim T, Kim DE, Jo EM, et al. The role of nafamostat mesylate anticoagulation in continuous kidney replacement therapy for critically ill patients with bleeding tendencies: a retrospective study on patient outcomes and safety. *Kidney Res Clin Pract* 2024;43:469-479. PUBMED | CROSSREF

110. Schmidt GA, Blaivas M, Conrad SA, et al. Ultrasound-guided vascular access in critical illness. *Intensive Care Med* 2019;45:434-446. PUBMED | CROSSREF

111. Franco-Sadud R, Schnobrich D, Mathews BK, et al. Recommendations on the use of ultrasound guidance for central and peripheral vascular access in adults: a position statement of the society of hospital medicine. *J Hosp Med* 2019;14:E1-E22. PUBMED | CROSSREF

112. Practice guidelines for central venous access 2020: an updated report by the American Society of Anesthesiologists task force on central venous access. *Anesthesiology* 2020;132:8-43. PUBMED | CROSSREF

113. Saugel B, Scheeren TWL, Teboul JL. Ultrasound-guided central venous catheter placement: a structured review and recommendations for clinical practice. *Crit Care* 2017;21:225. PUBMED | CROSSREF

114. Ehtesham AMM, Patkar C, Phalgune D. Study between ultrasound guided technique and conventional landmark technique for internal jugular vein cannulation: a randomised controlled trial. *J Clin Diagn Res* 2020;14:UC09-UC12. CROSSREF

115. Bansal R, Agarwal SK, Tiwari SC, Dash SC. A prospective randomized study to compare ultrasound-guided with nonultrasound-guided double lumen internal jugular catheter insertion as a temporary hemodialysis access. *Ren Fail* 2005;27:561-564. PUBMED | CROSSREF

116. Koroglu M, Demir M, Koroglu BK, et al. Percutaneous placement of central venous catheters: comparing the anatomical landmark method with the radiologically guided technique for central venous catheterization through the internal jugular vein in emergent hemodialysis patients. *Acta Radiol* 2006;47:43-47. PUBMED | CROSSREF

117. Kwon TH, Kim YL, Cho DK. Ultrasound-guided cannulation of the femoral vein for acute haemodialysis access. *Nephrol Dial Transplant* 1997;12:1009-1012. PUBMED | CROSSREF

118. Lam KK, Ng HY, Wu CH, Wu MT, Chen JB, Lee CT. Ultrasound localization of the femoral vein facilitates successful cannulation for hemodialysis. *Biomed J* 2013;36:237-242. PUBMED | CROSSREF

119. Lin BS, Huang TP, Tang GJ, Tarng DC, Kong CW. Ultrasound-guided cannulation of the internal jugular vein for dialysis vascular access in uremic patients. *Nephron J* 1998;78:423-428. PUBMED | CROSSREF

120. Prabhu MV, Juneja D, Gopal PB, et al. Ultrasound-guided femoral dialysis access placement: a single-center randomized trial. *Clin J Am Soc Nephrol* 2010;5:235-239. PUBMED | CROSSREF

121. Buetti N, Mimoz O, Mermel L, et al. Ultrasound guidance and risk for central venous catheter-related infections in the intensive care unit: a post hoc analysis of individual data of 3 multicenter randomized trials. *Clin Infect Dis* 2021;73:e1054-e1061. PUBMED | CROSSREF

122. Brass P, Hellmich M, Kolodziej L, Schick G, Smith AF. Ultrasound guidance versus anatomical landmarks for internal jugular vein catheterization. *Cochrane Database Syst Rev* 2015;1:CD006962. PUBMED | CROSSREF

123. Seleznova Y, Brass P, Hellmich M, Stock S, Müller D. Cost-effectiveness-analysis of ultrasound guidance for central venous catheterization compared with landmark method: a decision-analytic model. *BMC Anesthesiol* 2019;19:51. PUBMED | CROSSREF

124. Vegas A, Wells B, Braum P, et al. Guidelines for performing ultrasound-guided vascular cannulation: recommendations of the American Society of Echocardiography. *J Am Soc Echocardiogr* 2025;38:57-91. PUBMED | CROSSREF

125. Timsit JF, Baleine J, Bernard L, et al. Expert consensus-based clinical practice guidelines management of intravascular catheters in the intensive care unit. *Ann Intensive Care* 2020;10:118. PUBMED | CROSSREF

126. Fishman G, Singer P. Metabolic and nutritional aspects in continuous renal replacement therapy. *J Intensive Med* 2023;3:228-238. PUBMED | CROSSREF

127. McClave SA, Taylor BE, Martindale RG, et al. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.). *JPEN J Parenter Enteral Nutr* 2016;40:159-211. PUBMED | CROSSREF

128. Fiaccadori E, Sabatino A, Barazzoni R, et al. ESPEN guideline on clinical nutrition in hospitalized patients with acute or chronic kidney disease. *Clin Nutr* 2021;40:1644-1668. PUBMED | CROSSREF

129. Hung KY, Chen ST, Chu YY, Ho G, Liu WL. Nutrition support for acute kidney injury 2020-consensus of the Taiwan AKI task force. *J Chin Med Assoc* 2022;85:252-258. PUBMED | CROSSREF

130. Bellomo R, Cass A, Cole L, et al. Daily protein intake and patient outcomes in severe acute kidney injury: findings of the randomized evaluation of normal versus augmented level of replacement therapy (RENAL) trial. *Blood Purif* 2014;37:325-334. PUBMED | CROSSREF

131. Kritmetapak K, Peerapornratana S, Srisawat N, et al. The impact of macro-and micronutrients on predicting outcomes of critically ill patients requiring continuous renal replacement therapy. *PLoS One* 2016;11:e0156634. PUBMED | CROSSREF

132. Bufarah MNB, Costa NA, Losilla MPRP, et al. Low caloric and protein intake is associated with mortality in patients with acute kidney injury. *Clin Nutr ESPEN* 2018;24:66-70. PUBMED | CROSSREF

133. van Ruijven IM, Stapel SN, Girbes ARJ, Weijs PJM. Early high protein provision and mortality in ICU patients including those receiving continuous renal replacement therapy. *Eur J Clin Nutr* 2022;76:1303-1308. PUBMED | CROSSREF

134. Heyland DK, Patel J, Compher C, et al. The effect of higher protein dosing in critically ill patients with high nutritional risk (EFFORT Protein): an international, multicentre, pragmatic, registry-based randomised trial. *Lancet* 2023;401:568-576. PUBMED | CROSSREF

135. Scheinkestel CD, Adams F, Mahony L, et al. Impact of increasing parenteral protein loads on amino acid levels and balance in critically ill anuric patients on continuous renal replacement therapy. *Nutrition* 2003;19:733-740. PUBMED | CROSSREF

136. Scheinkestel CD, Kar L, Marshall K, et al. Prospective randomized trial to assess caloric and protein needs of critically Ill, anuric, ventilated patients requiring continuous renal replacement therapy. *Nutrition* 2003;19:909-916. PUBMED | CROSSREF

137. Reintam Blaser A, Rooyackers O, Bear DE. How to avoid harm with feeding critically ill patients: a synthesis of viewpoints of a basic scientist, dietitian and intensivist. *Crit Care* 2023;27:258. PUBMED | CROSSREF

138. Ostermann M, Lumlertgul N, Mehta R. Nutritional assessment and support during continuous renal replacement therapy. *Semin Dial* 2021;34:449-456. PUBMED | CROSSREF

139. Singer P, Blaser AR, Berger MM, et al. ESPEN guideline on clinical nutrition in the intensive care unit. *Clin Nutr* 2019;38:48-79. PUBMED | CROSSREF

140. Singer P, Blaser AR, Berger MM, et al. ESPEN practical and partially revised guideline: clinical nutrition in the intensive care unit. *Clin Nutr* 2023;42:1671-1689. PUBMED | CROSSREF

141. Macias WL, Alaka KJ, Murphy MH, Miller ME, Clark WR, Mueller BA. Impact of the nutritional regimen on protein catabolism and nitrogen balance in patients with acute renal failure. *JPEN J Parenter Enteral Nutr* 1996;20:56-62. PUBMED | CROSSREF

142. Berger MM, Shenkin A, Revelly JP, et al. Copper, selenium, zinc, and thiamine balances during continuous venovenous hemodiafiltration in critically ill patients. *Am J Clin Nutr* 2004;80:410-416. PUBMED | CROSSREF

143. Schneider AG, Picard W, Honoré PM, et al. Amino acids and vitamins status during continuous renal replacement therapy: an ancillary prospective observational study of a randomised control trial. *Anaesth Crit Care Pain Med* 2021;40:100813. PUBMED | CROSSREF

144. Gundogan K, Yucesoy FS, Ozer NT, et al. Serum micronutrient levels in critically ill patients receiving continuous renal replacement therapy: a prospective, observational study. *JPEN J Parenter Enteral Nutr* 2022;46:1141-1148. PUBMED | CROSSREF

145. Lumlertgul N, Cameron LK, Bear DE, Ostermann M. Micronutrient losses during continuous renal replacement therapy. *Nephron* 2023;147:759-765. PUBMED | CROSSREF

146. Garcia-Tsao G, Parikh CR, Viola A. Acute kidney injury in cirrhosis. *Hepatology* 2008;48:2064-2077. PUBMED | CROSSREF

147. Choi YJ, Kim JH, Koo JK, et al. Prevalence of renal dysfunction in patients with cirrhosis according to ADQI-IAC working party proposal. *Clin Mol Hepatol* 2014;20:185-191. PUBMED | CROSSREF

148. Friedman LS. The risk of surgery in patients with liver disease. *Hepatology* 1999;29:1617-1623. PUBMED | CROSSREF

149. Sedra AH, Strum E. The role of intraoperative hemodialysis in liver transplant patients. *Curr Opin Organ Transplant* 2011;16:323-325. PUBMED | CROSSREF

150. Karvellas CJ, Taylor S, Bigam D, et al. Intraoperative continuous renal replacement therapy during liver transplantation: a pilot randomized-controlled trial (INCEPTION). *Can J Anaesth* 2019;66:1151-1161. PUBMED | CROSSREF

151. LaMattina JC, Kelly PJ, Hanish SI, et al. Intraoperative continuous veno-venous hemofiltration facilitates surgery in liver transplant patients with acute renal failure. *Transplant Proc* 2015;47:1901-1904. PUBMED | CROSSREF

152. Safwan M, Gosnell J, Collins K, et al. Effects of intraoperative continuous renal replacement therapy on outcomes in liver transplantation. *Transplant Proc* 2020;52:265-270. PUBMED | CROSSREF

153. Baek SD, Jang M, Kim W, et al. Benefits of intraoperative continuous renal replacement therapy during liver transplantation in patients with renal dysfunction. *Transplant Proc* 2017;49:1344-1350. PUBMED | CROSSREF

154. Agopian VG, Dhillon A, Baber J, et al. Liver transplantation in recipients receiving renal replacement therapy: outcomes analysis and the role of intraoperative hemodialysis. *Am J Transplant* 2014;14:1638-1647. PUBMED | CROSSREF

155. Parmar A, Bigam D, Meeberg G, et al. An evaluation of intraoperative renal support during liver transplantation: a matched cohort study. *Blood Purif* 2011;32:238-248. PUBMED | CROSSREF

156. Zimmerman MA, Selim M, Kim J, et al. Outcome analysis of continuous intraoperative renal replacement therapy in the highest acuity liver transplant recipients: a single-center experience. *Surgery* 2017;161:1279-1286. PUBMED | CROSSREF

157. Zygun D. Non-neurological organ dysfunction in neurocritical care: impact on outcome and etiological considerations. *Curr Opin Crit Care* 2005;11:139-143. PUBMED | CROSSREF

158. Gruber A, Reinprecht A, Illievich UM, et al. Extracerebral organ dysfunction and neurologic outcome after aneurysmal subarachnoid hemorrhage. *Crit Care Med* 1999;27:505-514. PUBMED | CROSSREF

159. Büttner S, Stadler A, Mayer C, et al. Incidence, risk factors, and outcome of acute kidney injury in neurocritical care. *J Intensive Care Med* 2020;35:338-346. PUBMED | CROSSREF

160. Moore EM, Bellomo R, Nichol A, Harley N, Macisaac C, Cooper DJ. The incidence of acute kidney injury in patients with traumatic brain injury. *Ren Fail* 2010;32:1060-1065. PUBMED | CROSSREF

161. Covic A, Schiller A, Mardare NG, et al. The impact of acute kidney injury on short-term survival in an Eastern European population with stroke. *Nephrol Dial Transplant* 2008;23:2228-2234. PUBMED | CROSSREF

162. Wang D, Guo Y, Zhang Y, Li Z, Li A, Luo Y. Epidemiology of acute kidney injury in patients with stroke: a retrospective analysis from the neurology ICU. *Intern Emerg Med* 2018;13:17-25. PUBMED | CROSSREF

163. Zorrilla-Vaca A, Ziai W, Connolly ES Jr, Geocadin R, Thompson R, Rivera-Lara L. Acute kidney injury following acute ischemic stroke and intracerebral hemorrhage: a meta-analysis of prevalence rate and mortality risk. *Cerebrovasc Dis* 2018;45:1-9. PUBMED | CROSSREF

164. Zacharia BE, Ducruet AF, Hickman ZL, et al. Renal dysfunction as an independent predictor of outcome after aneurysmal subarachnoid hemorrhage: a single-center cohort study. *Stroke* 2009;40:2375-2381. PUBMED | CROSSREF

165. Tujjar O, Belloni I, Hougardy JM, et al. Acute kidney injury after subarachnoid hemorrhage. *J Neurosurg Anesthesiol* 2017;29:140-149. PUBMED | CROSSREF

166. Ramírez-Guerrero G, Baghetti-Hernández R, Ronco C. Acute kidney injury at the neurocritical care unit. *Neurocrit Care* 2022;36:640-649. PUBMED | CROSSREF

167. Messerer DAC, Halbgebauer R, Nilsson B, Pavenstädt H, Radermacher P, Huber-Lang M. Immunopathophysiology of trauma-related acute kidney injury. *Nat Rev Nephrol* 2021;17:91-111. PUBMED | CROSSREF

168. Kumar AB, Shi Y, Shotwell MS, Richards J, Ehrenfeld JM. Hypernatremia is a significant risk factor for acute kidney injury after subarachnoid hemorrhage: a retrospective analysis. *Neurocrit Care* 2015;22:184-191. PUBMED | CROSSREF

169. Sadan O, Singbartl K, Kraft J, et al. Low-chloride- versus high-chloride-containing hypertonic solution for the treatment of subarachnoid hemorrhage-related complications: the ACETatE (A low ChloriE hyperTonic solution for brain Edema) randomized trial. *J Intensive Care* 2020;8:32. PUBMED | CROSSREF

170. Qureshi AI, Palesch YY, Martin R, et al. Systolic blood pressure reduction and risk of acute renal injury in patients with intracerebral hemorrhage. *Am J Med* 2012;125:718.e1-718.e6. PUBMED | CROSSREF

171. Diprose WK, Sutherland LJ, Wang MTM, Barber PA. Contrast-associated acute kidney injury in endovascular thrombectomy patients with and without baseline renal impairment. *Stroke* 2019;50:3527-3531. PUBMED | CROSSREF

172. Pickkers P, Darmon M, Hoste E, et al. Acute kidney injury in the critically ill: an updated review on pathophysiology and management. *Intensive Care Med* 2021;47:835-850. PUBMED | CROSSREF

173. Patel P, Nandwani V, McCarthy PJ, Conrad SA, Keith Scott L. Continuous renal replacement therapies: a brief primer for the neurointensivist. *Neurocrit Care* 2010;13:286-294. PUBMED | CROSSREF

174. Davenport A, Will EJ, Davidson AM. Improved cardiovascular stability during continuous modes of renal replacement therapy in critically ill patients with acute hepatic and renal failure. *Crit Care Med* 1993;21:328-338. PUBMED | CROSSREF

175. Davenport A. Renal replacement therapy in the patient with acute brain injury. *Am J Kidney Dis* 2001;37:457-466. PUBMED | CROSSREF

176. Cruz-Llanos L, Molano A, Rizo-Topete L. Continuous renal replacement therapy in acute brain injury. *Front Nephrol* 2022;2:853677. PUBMED | CROSSREF

177. Davenport A, Will EJ, Davison AM. Early changes in intracranial pressure during haemofiltration treatment in patients with grade 4 hepatic encephalopathy and acute oliguric renal failure. *Nephrol Dial Transplant* 1990;5:192-198. PUBMED | CROSSREF

178. Tseng MF, Chou CL, Chung CH, et al. Continuous veno-venous hemofiltration yields better renal outcomes than intermittent hemodialysis among traumatic intracranial hemorrhage patients with acute kidney injury: a nationwide population-based retrospective study in Taiwan. *PLoS One* 2018;13:e0203088. PUBMED | CROSSREF

179. Kennedy AC, Linton AL, Luke RG, Renfrew S, Dinwoodie A. The pathogenesis and prevention of cerebral dysfunction during dialysis. *Lancet* 1964;1:790-793. PUBMED | CROSSREF

180. Bertrand YM, Hermant A, Mahieu P, Roels J. Intracranial pressure changes in patients with head trauma during haemodialysis. *Intensive Care Med* 1983;9:321-323. PUBMED | CROSSREF

181. Davenport A. Intradialytic complications during hemodialysis. *Hemodial Int* 2006;10:162-167. PUBMED | CROSSREF

182. Davenport A, Will EJ, Losowsky MS. Rebound surges of intracranial pressure as a consequence of forced ultrafiltration used to control intracranial pressure in patients with severe hepatorenal failure. *Am J Kidney Dis* 1989;14:516-519. PUBMED | CROSSREF

183. Davenport A. Renal replacement therapy for the patient with acute traumatic brain injury and severe acute kidney injury. *Contrib Nephrol* 2007;156:333-339. PUBMED | CROSSREF

184. Lund A, Damholt MB, Wiis J, Kelsen J, Strange DG, Møller K. Intracranial pressure during hemodialysis in patients with acute brain injury. *Acta Anaesthesiol Scand* 2019;63:493-499. PUBMED | CROSSREF

185. Zhu X, Han Q, Xia L, Shang J, Yan X. Efficacy of two hemodialyses in patients with chronic renal failure complicated by massive intracerebral hemorrhage. *Ann Clin Transl Neurol* 2023;10:1186-1199. PUBMED | CROSSREF

186. Parsons AD, Sanscrainte C, Leone A, Griepp DW, Rahme R. Dialysis disequilibrium syndrome and intracranial pressure fluctuations in neurosurgical patients undergoing renal replacement therapy: systematic review and pooled analysis. *World Neurosurg* 2023;170:2-6. PUBMED | CROSSREF

187. Davenport A. Practical guidance for dialyzing a hemodialysis patient following acute brain injury. *Hemodial Int* 2008;12:307-312. PUBMED | CROSSREF

188. Schmidt M, Pham T, Arcadipane A, et al. Mechanical ventilation management during extracorporeal membrane oxygenation for acute respiratory distress syndrome. an international multicenter prospective cohort. *Am J Respir Crit Care Med* 2019;200:1002-1012. PUBMED | CROSSREF

189. Gao P, Jin Y, Zhang P, Wang W, Hu J, Liu J. Nadir oxygen delivery is associated with postoperative acute kidney injury in low-weight infants undergoing cardiopulmonary bypass. *Front Cardiovasc Med* 2022;9:1020846. PUBMED | CROSSREF

190. Allyn J, Ferdynus C, Lo Pinto H, et al. Complication patterns in patients undergoing venoarterial extracorporeal membrane oxygenation in intensive care unit: multiple correspondence analysis and hierarchical ascendant classification. *PLoS One* 2018;13:e0203643. PUBMED | CROSSREF

191. Baek MS, Lee SM, Chung CR, et al. Improvement in the survival rates of extracorporeal membrane oxygenation-supported respiratory failure patients: a multicenter retrospective study in Korean patients. *Crit Care* 2019;23:1. PUBMED | CROSSREF

192. Brogan TV, Thiagarajan RR, Lorusso R, et al. The use of extracorporeal membrane oxygenation in human immunodeficiency virus-positive patients: a review of a multicenter database. *Perfusion* 2020;35:772-777. PUBMED | CROSSREF

193. Burke CR, Chan T, McMullan DM. Extracorporeal life support use in adult burn patients. *J Burn Care Res* 2017;38:174-178. PUBMED | CROSSREF

194. Chapman JT, Breeding J, Kerr SJ, Bajic M, Nair P, Buscher H. CNS complications in adult patients treated with extracorporeal membrane oxygenation. *Crit Care Med* 2021;49:282-291. PUBMED | CROSSREF

195. Combes A, Leprince P, Luyt CE, et al. Outcomes and long-term quality-of-life of patients supported by extracorporeal membrane oxygenation for refractory cardiogenic shock. *Crit Care Med* 2008;36:1404-1411. PUBMED | CROSSREF

196. Dado DN, Ainsworth CR, Thomas SB, et al. Outcomes among patients treated with renal replacement therapy during extracorporeal membrane oxygenation: a single-center retrospective study. *Blood Purif* 2020;49:341-347. PUBMED | CROSSREF

197. Dalia AA, Lu SY, Villavicencio M, et al. Extracorporeal cardiopulmonary resuscitation: outcomes and complications at a quaternary referral center. *J Cardiothorac Vasc Anesth* 2020;34:1191-1194. PUBMED | CROSSREF

198. Deatrick KB, Mazzeffi MA, Galvagno SM Jr, et al. Breathing life back into the kidney-continuous renal replacement therapy and veno-venous extracorporeal membrane oxygenation. *ASAIO J* 2021;67:208-212. PUBMED | CROSSREF

199. Devasagayaraj R, Cavarocchi NC, Hirose H. Does acute kidney injury affect survival in adults with acute respiratory distress syndrome requiring extracorporeal membrane oxygenation? *Perfusion* 2018;33:375-382. PUBMED | CROSSREF

200. Ding X, Xie H, Yang F, Wang L, Hou X. Risk factors of acute renal injury and in-hospital mortality in adult patients with postcardiotomy cardiogenic shock requiring veno-arterial extracorporeal membrane oxygenation: utility of MELD-XI score. *Perfusion* 2022;37:505-514. PUBMED | CROSSREF

201. Fong KM, Au SY, Ng GWY, Leung AKH. Positive fluid balance and mortality in adult patients treated with extracorporeal membrane oxygenation: a retrospective study. *J Intensive Care Soc* 2020;21:210-220. PUBMED | CROSSREF

202. Guru PK, Seelhammer TG, Singh TD, et al. Outcomes of adult patients supported by extracorporeal membrane oxygenation (ECMO) following cardiopulmonary arrest. The Mayo Clinic experience. *J Card Surg* 2021;36:3528-3539. PUBMED | CROSSREF

203. Han KS, Kim SJ, Lee EJ, Jung JS, Park JH, Lee SW. Experience of extracorporeal cardiopulmonary resuscitation in a refractory cardiac arrest patient at the emergency department. *Clin Cardiol* 2019;42:459-466. PUBMED | CROSSREF

204. Haneya A, Diez C, Philipp A, et al. Impact of acute kidney injury on outcome in patients with severe acute respiratory failure receiving extracorporeal membrane oxygenation. *Crit Care Med* 2015;43:1898-1906. PUBMED | CROSSREF

205. Harley O, Reynolds C, Nair P, Buscher H. Long-term survival, posttraumatic stress, and quality of life post extracorporeal membrane oxygenation. *ASAIO J* 2020;66:909-914. PUBMED | CROSSREF

206. Herrmann J, Lotz C, Karagiannidis C, et al. Key characteristics impacting survival of COVID-19 extracorporeal membrane oxygenation. *Crit Care* 2022;26:190. PUBMED | CROSSREF

207. Joo S, Cho S, Lee JH, et al. Postcardiotomy extracorporeal membrane oxygenation support in patients with congenital heart disease. *J Chest Surg* 2022;55:158-167. PUBMED | CROSSREF

208. Kielstein JT, Heiden AM, Beutel G, et al. Renal function and survival in 200 patients undergoing ECMO therapy. *Nephrol Dial Transplant* 2013;28:86-90. PUBMED | CROSSREF

209. Laimoud MAM, Qureshi R. Hospital outcomes after emergent peripheral veno-arterial extracorporeal membrane oxygenation in adult patients presenting with cardiogenic shock. *Signa Vitae* 2021;17:103-109.

210. Lim K, Choi JO, Yang JH, et al. Cardiac resynchronization therapy device implantation in a patient with cardiogenic shock under percutaneous mechanical circulatory support. *Korean Circ J* 2017;47:132-135. PUBMED | CROSSREF

211. Lumlertgul N, Wright R, Hutson G, et al. Long-term outcomes in patients who received veno-venous extracorporeal membrane oxygenation and renal replacement therapy: a retrospective cohort study. *Ann Intensive Care* 2022;12:70. PUBMED | CROSSREF

212. Luo XJW, Wang W, Sun HS, et al. Extracorporeal membrane oxygenation for treatment of cardiorespiratory function failure in adult patients. *Zhonghua Wai Ke Za Zhi* 2009;47:1563-1565. PUBMED

213. McCloskey CGE, Engoren MC. Transfusion and its association with mortality in patients receiving veno-arterial extracorporeal membrane oxygenation. *J Crit Care* 2022;68:42-47. PUBMED | CROSSREF

214. Natanov R, Kunkel ER, Wiesner O, et al. Determinants of survival in patients on extracorporeal membrane oxygenation therapy due to severe covid-19. *Perfusion* 2023;38:1393-1398. PUBMED | CROSSREF

215. Panholzer B, Meckelburg K, Huenges K, et al. Extracorporeal membrane oxygenation for acute respiratory distress syndrome in adults: an analysis of differences between survivors and non-survivors. *Perfusion* 2017;32:495-500. PUBMED | CROSSREF

216. Pappalardo F, Pieri M, Arnaez Corada B, et al. Timing and strategy for weaning from venoarterial ECMO are complex issues. *J Cardiothorac Vasc Anesth* 2015;29:906-911. PUBMED | CROSSREF

217. Park HS, Cho SJ, Ryu SM, et al. Analysis of the effect of renal replacement therapy: in the prolonged extracorporeal membrane oxygenation patients. *Korean J Thorac Cardiovasc Surg* 2014;47:373-377. PUBMED | CROSSREF

218. Schurr JWN, Noubani M, Santore LA, et al. Survival and outcomes after cardiac arrest with VA-ECMO rescue therapy. *Shock* 2021;56:939-947. PUBMED | CROSSREF

219. Thomas JMD, Dado DN, Basel AP, et al. Adjunct use of continuous renal replacement therapy with extracorporeal membrane oxygenation achieves negative fluid balance and enhances oxygenation which improves survival in critically ill patients without kidney failure. *Blood Purif* 2022;51:477-484. PUBMED | CROSSREF

220. Worku B, Khin S, Gaudino M, et al. Renal replacement therapy in patients on extracorporeal membrane oxygenation support: who and how. *Int J Artif Organs* 2021;44:531-538. PUBMED | CROSSREF

221. Wu MY, Lin PJ, Lee MY, et al. Using extracorporeal life support to resuscitate adult postcardiotomy cardiogenic shock: treatment strategies and predictors of short-term and midterm survival. *Resuscitation* 2010;81:1111-1116. PUBMED | CROSSREF

222. Yan X, Jia S, Meng X, et al. Acute kidney injury in adult postcardiotomy patients with extracorporeal membrane oxygenation: evaluation of the RIFLE classification and the Acute Kidney Injury Network criteria. *Eur J Cardiothorac Surg* 2010;37:334-338. PUBMED | CROSSREF

223. Yap HJ, Chen YC, Fang JT, Huang CC. Combination of continuous renal replacement therapies (CRRT) and extracorporeal membrane oxygenation (ECMO) for advanced cardiac patients. *Ren Fail* 2003;25:183-193. PUBMED | CROSSREF

224. Zhang J, Merrick B, Correa GL, et al. Veno-venous extracorporeal membrane oxygenation in coronavirus disease 2019: a case series. *ERJ Open Res* 2020;6:00463-2020. PUBMED | CROSSREF

225. Lee SYJ, Jeon KH, Lee HJ, et al. Complications of veno-arterial extracorporeal membrane oxygenation for refractory cardiogenic shock or cardiac arrest. *Int J Artif Organs* 2020;43:37-44. PUBMED | CROSSREF

226. Schmidt M, Bailey M, Kelly J, et al. Impact of fluid balance on outcome of adult patients treated with extracorporeal membrane oxygenation. *Intensive Care Med* 2014;40:1256-1266. PUBMED | CROSSREF

227. Burrell AJ, Pellegrino VA, Wolfe R, et al. Long-term survival of adults with cardiogenic shock after venoarterial extracorporeal membrane oxygenation. *J Crit Care* 2015;30:949-956. PUBMED | CROSSREF

228. Cho WH, Choi YY, Byun KS, et al. Prognostic value of sarcopenia for long-term mortality in extracorporeal membrane oxygenation for acute respiratory failure. *ASAIO J* 2020;66:367-372. PUBMED | CROSSREF

229. Antonucci E, Lamanna I, Fagnoul D, Vincent JL, De Backer D, Silvio Taccone F. The impact of renal failure and renal replacement therapy on outcome during extracorporeal membrane oxygenation therapy. *Artif Organs* 2016;40:746-754. PUBMED | CROSSREF

230. Braunsteiner J, Jarczak D, Schmidt-Lauber C, et al. Outcomes of critically ill coronavirus disease 2019 patients requiring kidney replacement therapy: a retrospective cohort study. *Front Med (Lausanne)* 2022;9:1027586. PUBMED | CROSSREF

231. Higashijima U, Sekino M, Egashira T, et al. Maximum and minimum lactate levels within 24 hours after veno-arterial extracorporeal membrane oxygenation induction are risk factors for intensive care unit mortality: a retrospective observational study. *Acta Med Nagasaki* 2020;63:61-69. CROSSREF

232. Extracorporeal Life Support Organization. ECLS international summary of statistics [Internet]. Extracorporeal Life Support Organization, 2025 [cited 2025 Oct 10] Available from: https://www.elso.org/registry/internationalsummaryandreports/internationalsummary.aspx.

233. Li C, Wang H, Liu N, Jia M, Hou X. The effect of simultaneous renal replacement therapy on extracorporeal membrane oxygenation support for postcardiotomy patients with cardiogenic shock: a pilot randomized controlled trial. *J Cardiothorac Vasc Anesth* 2019;33:3063-3072. PUBMED | CROSSREF

234. Paek JH, Park S, Lee A, et al. Timing for initiation of sequential continuous renal replacement therapy in patients on extracorporeal membrane oxygenation. *Kidney Res Clin Pract* 2018;37:239-247. PUBMED | CROSSREF

235. Lin YC, Lin YC, Lin FC, et al. Early continuous renal replacement therapy in cardiogenic shock patients with severe acute kidney injury undergoing extracorporeal membrane oxygenation. *Cardiorenal Med* 2014;4:130-139. CROSSREF

236. Beltramo F, DiCarlo J, Gruber JB, Taylor T, Totapally BR. Renal replacement therapy modalities in critically ill children. *Pediatr Crit Care Med* 2019;20:e1-e9. PUBMED | CROSSREF

237. Hayes LW, Oster RA, Tofil NM, Tolwani AJ. Outcomes of critically ill children requiring continuous renal replacement therapy. *J Crit Care* 2009;24:394-400. PUBMED | CROSSREF

238. Gillespie RS, Seidel K, Symons JM. Effect of fluid overload and dose of replacement fluid on survival in hemofiltration. *Pediatr Nephrol* 2004;19:1394-1399. PUBMED | CROSSREF

239. Foland JA, Fortenberry JD, Warshaw BL, et al. Fluid overload before continuous hemofiltration and survival in critically ill children: a retrospective analysis. *Crit Care Med* 2004;32:1771-1776. PUBMED | CROSSREF

240. Goldstein SL, Currier H, Graf Cd , Cosio CC, Brewer ED, Sachdeva R. Outcome in children receiving continuous venovenous hemofiltration. *Pediatrics* 2001;107:1309-1312. PUBMED | CROSSREF

241. Goldstein SL, Somers MJ, Baum MA, et al. Pediatric patients with multi-organ dysfunction syndrome receiving continuous renal replacement therapy. *Kidney Int* 2005;67:653-658. PUBMED | CROSSREF

242. Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Work Group. KDIGO clinical practice guideline for acute kidney injury. *Kidney Int Suppl* 2012;2:1-138.

243. Sutherland SM, Zappitelli M, Alexander SR, et al. Fluid overload and mortality in children receiving continuous renal replacement therapy: the prospective pediatric continuous renal replacement therapy registry. *Am J Kidney Dis* 2010;55:316-325. PUBMED | CROSSREF

244. Chen Z, Wang H, Wu Z, et al. Continuous renal-replacement therapy in critically ill children: practice changes and association with outcome. *Pediatr Crit Care Med* 2021;22:e605-e612. PUBMED | CROSSREF

245. Cortina G, McRae R, Hoq M, et al. Mortality of critically ill children requiring continuous renal replacement therapy: effect of fluid overload, underlying disease, and timing of initiation. *Pediatr Crit Care Med* 2019;20:314-322. PUBMED | CROSSREF

246. Gist KM, Misfeldt A, Sahay RD, et al. Acute kidney injury and fluid overload in pediatric extracorporeal cardio-pulmonary resuscitation: a multicenter retrospective cohort study. *ASAIO J* 2022;68:956-963. PUBMED | CROSSREF

247. Gorga SM, Lima L, Askenazi DJ, et al. Fluid balance management informs renal replacement therapy use during pediatric extracorporeal membrane oxygenation: a survey report from the Kidney Intervention During Extracorporeal Membrane Oxygenation Group. *ASAIO J* 2022;68:407-412. PUBMED | CROSSREF

248. Gorga SM, Sahay RD, Askenazi DJ, et al. Fluid overload and fluid removal in pediatric patients on extracorporeal membrane oxygenation requiring continuous renal replacement therapy: a multicenter retrospective cohort study. *Pediatr Nephrol* 2020;35:871-882. PUBMED | CROSSREF

249. Lee ST, Cho H. Fluid overload and outcomes in neonates receiving continuous renal replacement therapy. *Pediatr Nephrol* 2016;31:2145-2152. PUBMED | CROSSREF

250. Michael M, Kuehnle I, Goldstein SL. Fluid overload and acute renal failure in pediatric stem cell transplant patients. *Pediatr Nephrol* 2004;19:91-95. PUBMED | CROSSREF

251. Murphy HJ, Cahill JB, Twombley KE, Annibale DJ, Kiger JR. Implementing a practice change: early initiation of continuous renal replacement therapy during neonatal extracorporeal life support standardizes care and improves short-term outcomes. *J Artif Organs* 2018;21:76-85. PUBMED | CROSSREF

252. Park KS, Son KY, Hwang YS, et al. Outcome and prognosis in critically ill children receiving continuous renal replacement therapy. *J Korean Soc Pediatr Nephrol* 2007;11:247-254. CROSSREF

253. Sanchez-de-Toledo J, Perez-Ortiz A, Gil L, et al. Early initiation of renal replacement therapy in pediatric heart surgery is associated with lower mortality. *Pediatr Cardiol* 2016;37:623-628. PUBMED | CROSSREF

254. Selewski DT, Cornell TT, Blatt NB, et al. Fluid overload and fluid removal in pediatric patients on extracorporeal membrane oxygenation requiring continuous renal replacement therapy. *Crit Care Med* 2012;40:2694-2699. PUBMED | CROSSREF

255. Selewski DT, Cornell TT, Lombel RM, et al. Weight-based determination of fluid overload status and mortality in pediatric intensive care unit patients requiring continuous renal replacement therapy. *Intensive Care Med* 2011;37:1166-1173. PUBMED | CROSSREF

256. Wolf MJ, Chanani NK, Heard ML, Kanter KR, Mahle WT. Early renal replacement therapy during pediatric cardiac extracorporeal support increases mortality. *Ann Thorac Surg* 2013;96:917-922. PUBMED | CROSSREF

257. Modem V, Thompson M, Gollhofer D, Dhar AV, Quigley R. Timing of continuous renal replacement therapy and mortality in critically ill children. *Crit Care Med* 2014;42:943-953. PUBMED | CROSSREF

258. Allegretti AS, Steele DJ, David-Kasdan JA, Bajwa E, Niles JL, Bhan I. Continuous renal replacement therapy outcomes in acute kidney injury and end-stage renal disease: a cohort study. *Crit Care* 2013;17:R109. PUBMED | CROSSREF

259. Harris DG, McCrone MP, Koo G, et al. Epidemiology and outcomes of acute kidney injury in critically ill surgical patients. *J Crit Care* 2015;30:102-106. PUBMED | CROSSREF

260. Keleshian V, Kashani KB, Kompotiatis P, Barsness GW, Jentzer JC. Short, and long-term mortality among cardiac intensive care unit patients started on continuous renal replacement therapy. *J Crit Care* 2020;55:64-72. PUBMED | CROSSREF

261. Bouchard J, Cutter G, Mehta R. Timing of initiation of renal-replacement therapy in acute kidney injury. *N Engl J Med* 2020;383:1796-1798. PUBMED | CROSSREF

262. Boulware LE, Troll MU, Jaar BG, Myers DI, Powe NR. Identification and referral of patients with progressive CKD: a national study. *Am J Kidney Dis* 2006;48:192-204. PUBMED | CROSSREF

263. Agapito Fonseca J, Gameiro J, Marques F, Lopes JA. Timing of initiation of renal replacement therapy in sepsis-associated acute kidney injury. *J Clin Med* 2020;9:1413. PUBMED | CROSSREF

264. Clark E, Wald R, Walsh M, Bagshaw SM; Canadian Acute Kidney Injury (CANAKI) Investigators. Timing of initiation of renal replacement therapy for acute kidney injury: a survey of nephrologists and intensivists in Canada. *Nephrol Dial Transplant* 2012;27:2761-2767. PUBMED | CROSSREF

265. Lee J, Kim SG, Yun D, et al. Consulting to nephrologist when starting continuous renal replacement therapy for acute kidney injury is associated with a survival benefit. *PLoS One* 2023;18:e0281831. PUBMED | CROSSREF

266. Uchino S, Bellomo R, Morimatsu H, et al. Continuous renal replacement therapy: a worldwide practice survey. The Beginning and Ending Supportive Therapy for the Kidney (B.E.S.T. Kidney) investigators. *Intensive Care Med* 2007;33:1563-1570. PUBMED | CROSSREF

267. Kee YK, Kim EJ, Park KS, et al. The effect of specialized continuous renal replacement therapy team in acute kidney injury patients treatment. *Yonsei Med J* 2015;56:658-665. PUBMED | CROSSREF

268. Oh HJ, Lee MJ, Kim CH, et al. The benefit of specialized team approaches in patients with acute kidney injury undergoing continuous renal replacement therapy: propensity score matched analysis. *Crit Care* 2014;18:454. PUBMED | CROSSREF

269. Lee KH, Sol IS, Park JT, et al. Continuous renal replacement therapy (CRRT) in children and the specialized CRRT team: a 14-year single-center study. *J Clin Med* 2019;9:110. PUBMED | CROSSREF

270. Rhee H, Jang GS, Han M, et al. The role of the specialized team in the operation of continuous renal replacement therapy: a single-center experience. *BMC Nephrol* 2017;18:332. PUBMED | CROSSREF

271. Ruiz EF, Ortiz-Soriano VM, Talbott M, et al. Development, implementation and outcomes of a quality assurance system for the provision of continuous renal replacement therapy in the intensive care unit. *Sci Rep* 2020;10:20616. PUBMED | CROSSREF

272. Shimada H, Kataoka Y, Tsunemitsu T, Takeoka H. The effectiveness of a specialized team intervention on prognosis in patients undergoing continuous renal replacement therapy: a retrospective cohort study. *Clin Nephrol* 2021;95:87-92. PUBMED | CROSSREF

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Review Article

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Advances in Hyperkalemia Management and the Emerging Role of Sodium Zirconium Cyclosilicate

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ABSTRACT

Hyperkalemia is a common and potentially life-threatening complication in patients with chronic kidney disease and heart failure. It also represents a major barrier to the optimal use of renin-angiotensin-aldosterone system inhibitors (RAASi), which are central to improving cardiorenal outcomes. Contemporary guidance, including the 2025 Korean Society of Nephrology Practical Recommendations for the Management of Hypertensive Kidney Disease, emphasizes the maintenance of normokalemia as a key strategy for enabling continuation and optimization of RAASi therapy. Sodium zirconium cyclosilicate (SZC) supports this therapeutic paradigm by enabling rapid potassium reduction and sustained potassium control. This review repositions hyperkalemia as a modifiable barrier to guideline-directed therapy and summarizes the pharmacology, clinical evidence, and practical considerations related to SZC use in patients at high cardiorenal risk.

Keywords: Heart failure; Hyperkalemia; Kidney diseases; Potassium; Zirconium

FROM ELECTROLYTE DISTURBANCE TO THERAPEUTIC BARRIER

Hyperkalemia is a frequent and clinically significant complication in patients with chronic kidney disease (CKD), heart failure (HF), and diabetes mellitus. Impaired renal potassium excretion, combined with the widespread use of renin-angiotensin-aldosterone system inhibitors (RAASi), contributes to the high incidence of hyperkalemia in these populations. Epidemiologic studies indicate that up to 40–50% of patients with advanced CKD or HF experience at least one episode of hyperkalemia during the course of treatment [1]. Even mild elevations in serum potassium are associated with increased risks of arrhythmia, hospitalization, and mortality, underscoring the importance of effective potassium management.

Beyond its direct clinical risks, hyperkalemia represents a major barrier to the optimal implementation of guideline-directed medical therapy for cardiorenal disease. RAASi—including angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, and mineralocorticoid receptor antagonists (MRAs)—are fundamental therapies that reduce

Data sharing statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Authors' contributions

Conceptualization: JJ, SJ, ESK, SC; Supervision: JJ, SJ, ESK, SC; Writing - original draft: JJ, SJ, ESK, SC; Writing - review & editing: JJ, SJ, ESK, SC.

mortality, slow CKD progression, and improve cardiovascular outcomes [2]. However, the development of hyperkalemia frequently necessitates dose reduction or discontinuation of these agents. Observational studies consistently demonstrate that RAASi discontinuation following hyperkalemia is associated with worse cardiovascular and renal outcomes, highlighting the clinical importance of maintaining potassium homeostasis while preserving life-saving pharmacotherapy [3,4].

Traditional approaches to hyperkalemia management have focused primarily on acute potassium reduction through dietary restriction, temporary medication adjustments, and short-acting pharmacologic interventions [5]. Although effective in emergency settings, these strategies are often insufficient for the long-term potassium control required in patients with chronic cardiorenal disease. Conventional potassium-binding resins such as sodium polystyrene sulfonate and calcium polystyrene sulfonate have been used for decades; however, their unpredictable onset of action and potential gastrointestinal toxicity limit their suitability for chronic therapy [6-8]. As a result, clinicians frequently face a therapeutic dilemma between maintaining RAASi therapy and avoiding recurrent hyperkalemia.

Recent clinical guidelines have increasingly emphasized the importance of sustained potassium control as an enabling strategy for cardiorenal therapy. The Kidney Disease: Improving Global Outcomes (KDIGO) 2024 clinical practice guideline and the 2025 Korean Society of Nephrology (KSN) Practical Recommendations for the Management of Hypertensive Kidney Disease both recognize potassium-lowering therapies as an important means of supporting the continued use of RAASi rather than reducing or discontinuing these agents [9,10]. This evolving paradigm reframes hyperkalemia not merely as an electrolyte abnormality requiring correction, but as a modifiable barrier to the optimal delivery of evidence-based treatments.

Sodium zirconium cyclosilicate (SZC) is a novel, non-absorbed potassium-binding compound designed to selectively trap potassium ions within the gastrointestinal tract [11]. Through rapid and sustained potassium reduction, SZC offers a potential strategy to stabilize serum potassium levels and enable the continuation of RAASi therapy in patients at high cardiorenal risk. In this review, we examine the pharmacologic properties of SZC, summarize the clinical evidence supporting its use, and discuss its role in contemporary strategies for the management of hyperkalemia in patients with CKD and cardiovascular disease.

PHARMACOLOGY AND MECHANISM OF ACTION OF SZC

SZC (formerly ZS-9) is a non-absorbed inorganic crystalline compound characterized by a cubic lattice structure containing uniform micropores of approximately 3 Ångström (Å) in diameter (**Fig. 1**) [12]. This structural configuration functions as a selective filter that mimics physiologic potassium channels.

SZC demonstrates more than 25-fold selectivity for potassium ions (K^+) compared with divalent cations such as calcium (Ca^{2+}) and magnesium (Mg^{2+}) [13]. This selectivity minimizes the nonspecific electrolyte binding commonly observed with conventional resins. Pharmacodynamic studies indicate that potassium reduction may begin within one hour after administration, with a median time to normokalemia of approximately 2.2 hours (**Table 1**) [13-21].

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Table 1. Comparative characteristics of medications used to treat hyperkalemia

Category	Sodium zirconium cyclosilicate (LOKELMA®)	Calcium polystyrene sulfonate	Sodium polystyrene sulfonate	Patiromer sorbitex calcium
Regulatory basis	FDA [13], EMA [14], MFDS [16]	MFDS [18]	FDA [19]	FDA [20], EMA [21]
Drug class	Inorganic potassium binder	Cation-exchange resin	Cation-exchange resin	Non-absorbed polymer potassium binder
Potassium selectivity	Highly selective for K^+	Non-selective (binds K^+ and Mg^{2+})	Non-selective (binds K^+, Ca^{2+}, Mg^{2+})	Selective for K^+
Mechanism of action	Inorganic crystal lattice that selectively traps K^+ in exchange for Na^+ and H^+	Exchanges Ca^{2+} for K^+ in the gastrointestinal tract	Exchanges Na^+ for K^+ in the gastrointestinal tract	Exchanges Ca^{2+} for K^+ in the colon
Site of potassium binding	Small and large intestine	Primarily colon	Primarily colon	Primarily colon
Onset of action	~1 hr	Variable (hours to days)	Variable (hours to days)	~4–7 hr
Sodium/calcium load	Sodium ~0.4 g per 5 g dose	Calcium ~0.5 g per 5 g dose	Sodium ~1.5 g per 15 g dose	Calcium ~1.6 g per 8.4 g dose
Dosing frequency	TID for correction, then once daily for maintenance	1–3 times daily	1–4 times daily	Once daily
Drug-drug interaction spacing	≥ 2 hr for pH-dependent drugs	≥ 3 hr	≥ 3 hr	≥ 3 hr
Common adverse effects	Edema, hypokalemia, mild gastrointestinal symptoms	Constipation, hypercalcemia, rare GI necrosis	Constipation, sodium overload, rare GI necrosis	Constipation, flatulence, hypomagnesemia
Preparation	Suspend in ~45 mL water	Suspend in 30–50 mL water	Suspend in 20–100 mL water or syrup	Suspend in ≥ 40 mL water
Storage	Room temperature	Room temperature	Room temperature	Refrigeration recommended

EMA, European Medicines Agency; FDA, Food and Drug Administration; GI, Gastrointestinal; MFDS, Ministry of Food and Drug Safety; TID, three times a day.

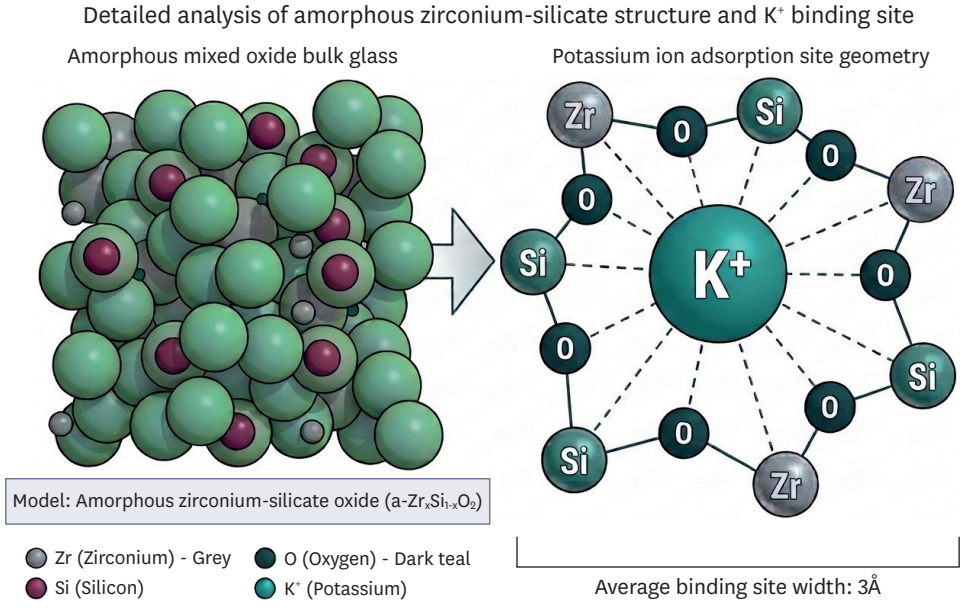

Fig. 1. Crystal structure of SZC.
The SZC framework consists of Zr and Si atoms coordinated with oxygen in octahedral and tetrahedral geometries, respectively. Shared oxygen atoms link these units to form a well-ordered microporous cubic structure. The pore opening is formed by an asymmetrical seven-membered ring. SZC selectively captures K^+ ions through a selectivity filter analogous to that of physiologic potassium channels [10]. Å is a metric unit of length equal to 10-10 m (0.1 nanometer).
SZC, sodium zirconium cyclosilicate.

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CLINICAL EVIDENCE OF SZC

The clinical development program for SZC evaluated its efficacy across multiple stages of hyperkalemia management, including acute correction and long-term maintenance therapy. Collectively, these trials provide evidence for the drug's role in achieving rapid potassium reduction and maintaining normokalemia in diverse patient populations, thereby supporting the continued use of organ-protective therapies (**Table 2**) [11,15,22-26].

Rapid correction: defining onset and predictability

In the phase 3 randomized placebo-controlled ZS-003 trial, SZC demonstrated a significant dose-dependent reduction in serum potassium levels [22]. A mean decrease of 0.11 mmol/L (95% confidence interval [CI], −0.17 to −0.05) was observed within one hour after the initial 10-g dose, whereas potassium levels increased slightly in the placebo group (0.01 mmol/L). After 48 hours, potassium levels decreased by 0.5 mmol/L and 0.7 mmol/L in the 5-g and 10-g groups, respectively ($p < 0.001$).

Similar findings were observed in the HARMONIZE trial, where 98% of patients achieved normokalemia during the acute correction phase using 10 g three times daily, with a median time to normalization of 2.2 hours [15]. A pooled analysis of phase 3 trials showed that adverse events were generally mild and primarily gastrointestinal in nature (2.9%), with no serious adverse events reported during the correction phase [27].

The HARMONIZE-Global study, which included a population composed of more than 85% Asian participants, further confirmed these results. Normokalemia was achieved as early as 4 hours after treatment initiation in many patients, increasing to 89.1% by 48 hours (95% CI, 84.8 to 92.6) [23]. These findings indicate that the rapid potassium-lowering effect of SZC is consistent across diverse ethnic populations.

Table 2. Summary of major clinical trials evaluating SZC

Study name	Study population	Study design	Dosing regimen	Duration	Key findings
ZS-003 [22]	Adults with hyperkalemia (K^+ 5.0–6.5 mmol/L)	Phase 3 randomized, placebo-controlled trial evaluating correction and short-term maintenance	1.25–10 g three times daily for correction, followed by once-daily maintenance	14 days	Rapid potassium reduction within 1 hr and significant dose-dependent decreases in serum potassium
HARMONIZE [15]	Hyperkalemic patients ($K^+ \geq 5.1$ mmol/L) with high prevalence of CKD, HF, and diabetes	Phase 3 randomized trial with correction phase followed by randomized withdrawal maintenance phase	10 g three times daily for 48 h, followed by 5–15 g once daily	30 days	98% achieved normokalemia during correction phase; sustained potassium control during maintenance phase
HARMONIZE-Global [23]	Outpatients with hyperkalemia (predominantly Asian population)	Randomized, double-blind, placebo-controlled trial	10 g three times daily for correction followed by once-daily maintenance	28 days	Rapid potassium reduction with high rates of normokalemia maintained during treatment
ZS-004E [11]	Patients completing or discontinuing the HARMONIZE maintenance phase	Open-label extension study evaluating long-term potassium control	Initial 10 g once daily, titrated to 5–15 g according to potassium level	11 mo	Mean serum potassium 4.7 mmol/L; 88% maintained $K^+ < 5.1$ mmol/L during long-term therapy
ZS-005 [24]	Patients with hyperkalemia from prior SZC trials (ZS-003 and HARMONIZE)	Phase 3 open-label long-term extension study	5–15 g once daily, titrated according to serum potassium	12 mo	88% maintained $K^+ \leq 5.1$ mmol/L; 87% maintained or increased RAAS inhibitor therapy
REALIZE-K [25]	Patients with HFrEF receiving spironolactone	Randomized clinical trial evaluating MRA optimization	SZC titrated to maintain normokalemia during spironolactone therapy	6 mo	SZC significantly increased the likelihood of maintaining guideline-recommended MRA doses
DIALIZE [26]	Patients with ESRD receiving hemodialysis	Phase 3b randomized, double-blind, placebo-controlled trial	5–15 g once daily on non-dialysis days	8 wk	Significantly increased proportion of patients achieving predialysis normokalemia during the long interdialytic interval

CKD, chronic kidney disease; ESRD, end-stage renal disease; HF, heart failure; HFrEF, heart failure with reduced ejection fraction; MRA, mineralocorticoid receptor antagonist; RAAS, renin-angiotensin-aldosterone system; SZC, sodium zirconium cyclosilicate.

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Sustained maintenance and enablement of RAASi

Following acute correction, sustained potassium control is necessary to prevent RAASi dose reduction or discontinuation. Evidence for the durability of SZC therapy was first demonstrated in the maintenance phase of the ZS-003 trial, in which SZC 5 g and 10 g maintained mean potassium levels at 4.7 mmol/L and 4.5 mmol/L, respectively, through day 14. In contrast, potassium levels in the placebo group exceeded 5.0 mmol/L ($p = 0.008$ and $p < 0.001$, respectively) [22]. Further evidence from the ZS-004 trial demonstrated that once-daily SZC significantly reduced serum potassium levels over 28 days compared with placebo [11]. These findings were reinforced in the randomized withdrawal phase of the HARMONIZE trial, where once-daily SZC (5 g, 10 g, or 15 g) maintained significantly lower mean potassium levels (4.8, 4.5, and 4.4 mmol/L) compared with placebo (5.1 mmol/L) during days 8–29 ($p < 0.001$) [15].

Long-term evidence was provided by the 12-month ZS-005 study, which demonstrated that 88% of patients maintained potassium levels ≤ 5.1 mmol/L during one year of therapy, while 87% maintained or increased their RAASi dose [24]. In patients with HF with reduced ejection fraction, the REALIZE-K trial further demonstrated that SZC significantly increased the likelihood of maintaining guideline-recommended doses of MRAs [25].

These findings are supported by real-world evidence from the multinational ZORA study, which showed that patients receiving SZC after a hyperkalemic episode were more than twice as likely to maintain RAASi therapy at six months compared with patients who did not receive a potassium binder (odds ratio, 2.56; 95% CI, 1.92 to 3.41) [28]. Importantly, RAASi discontinuation or dose reduction following hyperkalemia was associated with a markedly higher short-term risk of adverse renal outcomes.

Together, these data highlight hyperkalemia as a modifiable barrier to optimal cardiorenal therapy, and demonstrate how effective potassium management can support sustained use of guideline-directed treatments.

Dialysis and healthcare resource utilization

Specialized trials have addressed populations with unique clinical needs. In a Phase 3b, Multicenter, Prospective, Randomized, Double Blind, Placebocontrolled Study to Reduce Incidence of Pre-dialysis Hyperkalemia With Sodium Zirconium Cyclosilicate (DIALIZE) trial, SZC administered on non-dialysis days significantly increased the proportion of patients maintaining predialysis normokalemia during the long interdialytic interval (41.2% vs. 1.0% with placebo, $p < 0.001$) [26]. This study addressed the critical need for interdialytic potassium management in hemodialysis patients.

In the retrospective RECOGNIZE I study, significantly lower proportions of outpatient clinic patients with hyperkalemia on long-term SZC therapy had hyperkalemia-related hospitalization (10.1% vs. 15.1%) and all-cause hospitalization (22.5% vs. 29.3%) during the follow-up period compared with those who received short-term therapy [29]. Furthermore, the GALVANIZE Outcome study, a non-interventional, retrospective, observational cohort study comparing healthcare resource utilization outcomes in matched patients treated with short-term (≤ 30 days) or long-term (> 90 days) outpatient SZC therapy, has shown that long-term SZC use is associated with significant reductions in hyperkalemia-related hospitalizations or emergency department visits compared with short-term use among patients with HF or cardio/renal dysfunction [30]. These data suggest that long-term

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maintenance SZC therapy may be associated with a reduced risk of hyperkalemia-related utilization of healthcare resources in patients with either kidney or heart disease.

Clinical practice considerations

Current clinical guidelines increasingly recognize potassium binders as enabling therapies that support the continued use of RAASi. Both the KDIGO 2024 Clinical Practice Guideline for CKD and the KSN 2025 recommendations identify SZC as a strategy that allows RAASi continuation rather than dose reduction [9,10].

Fluid-related adverse effects, including edema associated with sodium load, may occur in susceptible patients but are generally manageable through appropriate diuretic adjustment [13]. To minimize potential drug–drug interactions, a two-hour dosing separation is recommended for medications with pH-dependent absorption, including azole antifungals (e.g., ketoconazole), HIV antivirals (e.g., atazanavir), and certain tyrosine kinase inhibitors (e.g., erlotinib and dasatinib) [13,14].

Compared with other newer potassium binders such as patiromer, SZC is characterized by a more rapid onset of action, which may provide advantages in acute or peri-titration clinical settings [31]. Nonetheless, the choice of potassium-lowering therapy should ultimately be individualized according to patient characteristics and treatment goals.

CONCLUSION

SZC represents a predictable and effective pharmacologic option for the management of hyperkalemia. By achieving rapid potassium reduction and sustained normokalemia, SZC facilitates the continued use of guideline-directed medical therapies in patients at high cardiorenal risk. Evidence from both clinical trials and real-world studies indicates that effective potassium management improves persistence with life-saving RAAS inhibitor therapy.

Consequently, the integration of SZC into clinical practice may promote therapeutic continuity and contribute to improved outcomes in cardiorenal disease. With its recent introduction in Korea under the brand name Lokelma, SZC is expected to address long-standing unmet needs in hyperkalemia management and support optimization of cardiorenal care. After nearly seven decades with limited innovation in pharmacologic therapy for hyperkalemia, the emergence of new potassium-binding agents marks the beginning of a new era in its management.

REFERENCES

1. Palmer BF, Carrero JJ, Clegg DJ, et al. Clinical management of hyperkalemia. *Mayo Clin Proc* 2021;96:744-762. PUBMED | CROSSREF
2. Rosano GMC, Tamargo J, Kjeldsen KP, et al. Expert consensus document on the management of hyperkalaemia in patients with cardiovascular disease treated with renin angiotensin aldosterone system inhibitors: coordinated by the Working Group on Cardiovascular Pharmacotherapy of the European Society of Cardiology. *Eur Heart J Cardiovasc Pharmacother* 2018;4:180-188. PUBMED | CROSSREF
3. Epstein M, Reaven NL, Funk SE, McGaughey KJ, Oestreicher N, Knispel J. Evaluation of the treatment gap between clinical guidelines and the utilization of renin-angiotensin-aldosterone system inhibitors. *Am J Manag Care* 2015;21:S212-S220. PUBMED

https://doi.org/10.5049/EBP.2026.24.e3

4. Rossignol P, Dobre D, McMurray JJ, et al. Incidence, determinants, and prognostic significance of hyperkalemia and worsening renal function in patients with heart failure receiving the mineralocorticoid receptor antagonist eplerenone or placebo in addition to optimal medical therapy: results from the Eplerenone in Mild Patients Hospitalization and Survival Study in Heart Failure (EMPHASIS-HF). *Circ Heart Fail* 2014;7:51-58. PUBMED | CROSSREF
5. Ahn YH, Kang HG, Song J, et al. Dietary management of pediatric patients with kidney disease: recommendations by The Korean Society of Pediatric Nephrology and The Korean Society of Clinical Nutrition. *Kidney Res Clin Pract* 2025;44:863-874. PUBMED | CROSSREF
6. Sterns RH, Rojas M, Bernstein P, Chennupati S. Ion-exchange resins for the treatment of hyperkalemia: are they safe and effective? *J Am Soc Nephrol* 2010;21:733-735. PUBMED | CROSSREF
7. Noel JA, Bota SE, Petrcich W, et al. Risk of hospitalization for serious adverse gastrointestinal events associated with sodium polystyrene sulfonate use in patients of advanced age. *JAMA Intern Med* 2019;179:1025-1033. PUBMED | CROSSREF
8. Dépret F, Peacock WF, Liu KD, Rafique Z, Rossignol P, Legrand M. Management of hyperkalemia in the acutely ill patient. *Ann Intensive Care* 2019;9:32. PUBMED | CROSSREF
9. The Korean Society of Nephrology. The Korean Society of Nephrology 2025 practical recommendations for the management of hypertensive kidney disease [Internet]. The Korean Society of Nephrology, c2025 [cited 2025 Jul 10]. Available from: https://ksn.or.kr/bbs/index.php?page=2&code=guideline_k
10. Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2024 clinical practice guideline for the evaluation and management of chronic kidney disease. *Kidney Int* 2024;105:S117-S314. PUBMED | CROSSREF
11. Hoy SM. Sodium zirconium cyclosilicate: a review in hyperkalaemia. *Drugs* 2018;78:1605-1613. PUBMED | CROSSREF
12. Stavros F, Yang A, Leon A, Nuttall M, Rasmussen HS. Characterization of structure and function of ZS-9, a K+ selective ion trap. *PLoS One* 2014;9:e114686. PUBMED | CROSSREF
13. U.S. Food and Drug Administration. New Drug Application (NDA): 207078 [Internet]. U.S. Food and Drug Administration, c2024 [cited 2024 Feb 8]. Available from https://www.accessdata.fda.gov/drugsatfda_docs/label/2024/207078s010lbl.pdf
14. European Medicines Agency. Lokelma (sodium zirconium cyclosilicate) [Internet]. European Medicines Agency, c2025 [cited 2025 Mar 9]. Available from https://www.ema.europa.eu/en/medicines/human/EPAR/lokelma
15. Kosiborod M, Rasmussen HS, Lavin P, et al. Effect of sodium zirconium cyclosilicate on potassium lowering for 28 days among outpatients with hyperkalemia: the HARMONIZE randomized clinical trial. *JAMA* 2014;312:2223-2233. PUBMED | CROSSREF
16. Ministry of Food and Drug Safety. LOKELMA (sodium zirconium cyclosilicate) [Internet]. Ministry of Food and Drug Safety, c2025 [cited 2025 Nov 28]. Available from: https://nedrug.mfds.go.kr/pbp/CCBBB01/getItemDetailCache?cacheSeq=202503117aupdateTs2026-03-06%2015:55:35.516339b
17. Palmer BF. Managing hyperkalemia caused by inhibitors of the renin-angiotensin-aldosterone system. *N Engl J Med* 2004;351:585-592. PUBMED | CROSSREF
18. Ministry of Food and Drug Safety. KALIMATE (calcium polystyrene sulfonate) [Internet]. Ministry of Food and Drug Safety, c2027 [cited 2027 Aug 29]. Available from: https://nedrug.mfds.go.kr/pbp/CCBBB01/getItemDetailCache?cacheSeq=201706859aupdateTs2026-02-09%2012:07:56.0b
19. U.S. Food and Drug Administration. New Drug Application (NDA): 011287 [Internet]. U.S. Food and Drug Administration, c2017 [cited 2017 Jul 28]. Available from https://www.accessdata.fda.gov/drugsatfda_docs/label/2009/011287s022lbl.pdf
20. U.S. Food and Drug Administration. New Drug Application (NDA): 205739 [Internet]. U.S. Food and Drug Administration, c2023 [cited 2023 Oct 2]. Available from https://www.accessdata.fda.gov/drugsatfda_docs/label/2023/205739Orig1s038lbl.pdf
21. European Medicines Agency. Veltassa (patiromer) [Internet]. European Medicines Agency, c2024 [cited 2024 Nov 6]. Available from https://www.ema.europa.eu/en/medicines/human/EPAR/veltassa
22. Packham DK, Rasmussen HS, Lavin PT, et al. Sodium zirconium cyclosilicate in hyperkalemia. *N Engl J Med* 2015;372:222-231. PUBMED | CROSSREF
23. Zannad F, Hsu BG, Maeda Y, et al. Efficacy and safety of sodium zirconium cyclosilicate for hyperkalaemia: the randomized, placebo-controlled HARMONIZE-Global study. *ESC Heart Fail* 2020;7:54-64. PUBMED | CROSSREF
24. Spinowitz BS, Fishbane S, Pergola PE, et al. Sodium zirconium cyclosilicate among individuals with hyperkalemia: a 12-month phase 3 study. *Clin J Am Soc Nephrol* 2019;14:798-809. PUBMED | CROSSREF

25. Kosiborod MN, Cherney DZI, Desai AS, et al. Sodium zirconium cyclosilicate for management of hyperkalemia during spironolactone optimization in patients with heart failure. *J Am Coll Cardiol* 2025;85:971-984. PUBMED | CROSSREF

26. Fishbane S, Ford M, Fukagawa M, et al. A phase 3b, randomized, double-blind, placebo-controlled study of sodium zirconium cyclosilicate for reducing the incidence of predialysis hyperkalemia. *J Am Soc Nephrol* 2019;30:1723-1733. PUBMED | CROSSREF

27. Amin AN, Menoyo J, Singh B, Kim CS. Efficacy and safety of sodium zirconium cyclosilicate in patients with baseline serum potassium level ≥ 5.5 mmol/L: pooled analysis from two phase 3 trials. *BMC Nephrol* 2019;20:440. PUBMED | CROSSREF

28. Rastogi A, Pollack CV Jr, Sánchez Lázaro IJ, et al. Maintained renin-angiotensin-aldosterone system inhibitor therapy with sodium zirconium cyclosilicate following a hyperkalaemia episode: a multicountry cohort study. *Clin Kidney J* 2024;17:sfae083. PUBMED | CROSSREF

29. Pollack CV Jr, Agiro A, Mu F, et al. Impact on hospitalizations of long-term versus short-term therapy with sodium zirconium cyclosilicate during routine outpatient care of patients with hyperkalemia: the recognize I study. *Expert Rev Pharmacoecon Outcomes Res* 2023;23:241-250. PUBMED | CROSSREF

30. Agiro A, Mu F, Cook EE, et al. Sodium zirconium cyclosilicate duration and hyperkalemia-related healthcare encounters in patients with heart failure and cardio/renal dysfunction: the GALVANIZE outcome study. *Drugs Real World Outcomes* 2025;12:655-667. PUBMED | CROSSREF

31. Mehta M, Auguste B. Are newer potassium binding agents truly better? rethinking sodium polystyrene sulfate and emerging therapies for hyperkalemia. *J Gen Intern Med* 2025;40:516-517. PUBMED | CROSSREF

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Letter to the Editor

In Memoriam: Jung Sang Lee, MD, PhD (1942–2026), A Pioneer of Korean Nephrology and Visionary Medical Educator

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Professor Jung Sang Lee, a founding figure of Korean nephrology and Emeritus Professor at Seoul National University College of Medicine, passed away on January 8, 2026, at the age of 84. His career spanned more than four decades. During this time, he established the Division of Nephrology at Seoul National University Hospital (SNUH), led clinical practice and research across the broad spectrum of nephrology, contributed to the diagnosis and management of acute febrile illnesses with renal involvement, served as the 5th President of the Korean Society of Nephrology (KSN), and led major reforms in medical education as Dean of Seoul National University College of Medicine. His legacy as a clinician, researcher, educator, and institutional leader significantly shaped medicine in Korea.

Professor Lee was born on January 6, 1942, in Korea. He came of age during a period of national reconstruction following the Korean War, when the country's healthcare infrastructure was rudimentary and the burden of infectious and chronic diseases far exceeded the capacity of the medical system. He graduated from Seoul National University College of Medicine in 1966 and subsequently earned both his Master's and Doctoral degrees from the same institution. From 1966 to 1971, he completed his internship and internal medicine residency at SNUH, a formative period that exposed him to the devastating clinical consequences of kidney disease and systemic infections. Even before subspecialty training was formally established in Korean internal medicine, he recognized the critical importance

Data sharing statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Authors' contributions

Conceptualization: SK; Data curation: JL; Formal analysis: JL; Investigation: JL, SK; Methodology: JL, SK; Project administration: SK; Resources: SK; Software: JL; Supervision: SK; Validation: SK; Visualization: JL; Writing - original draft: JL; Writing - review & editing: JL, SK.

of nephrology as an independent discipline. After serving as an instructor and then assistant professor at Seoul National University College of Medicine from 1974, he undertook a fellowship at Northwestern University Medical School in Chicago, USA (1976–1978), where he gained advanced training in nephrology and exposure to cutting-edge renal physiology research. This international experience deepened his conviction that Korea needed its own robust nephrology program, and upon his return, he devoted himself to building one.

One of the most significant achievements of Professor Lee's career was the establishment of the Division of Nephrology at SNUH. In the late 1960s and early 1970s, the treatment of kidney disease in Korea was virtually nonexistent. Hemodialysis, the only available renal replacement therapy, required expensive equipment and sophisticated operational systems that were largely inaccessible. He devoted himself to establishing an independent Division of Nephrology. In 1969, the "Kolff rotating drum artificial kidney," a hemodialysis machine developed by Professor Kolff at the University of Utah and the first to enable practical clinical hemodialysis, was introduced to the Fifth Department of Internal Medicine at the SNUH. Professor Lee, together with members of the clinical unit, carried water from a bathhouse near the hospital boiler room to prepare dialysate and continued to provide patient care under these demanding conditions. These early efforts ultimately laid the foundation for the dialysis unit and Division of Nephrology. Building upon these clinical experiences, Professor Lee established systematic protocols encompassing dialysate composition, the management of dialysis-related complications, and the nutritional and electrolyte care of uremic patients. These foundations subsequently contributed to the improved outcomes of dialysis therapy in Korea.

Professor Lee's scholarly impact extended far beyond nephrology into the realm of infectious disease epidemiology, where he played a pivotal role in identifying previously unrecognized causes of febrile illness in Korea. In 1984, he confirmed leptospirosis as the cause of an acute hemorrhagic febrile illness that had recurred in rural areas during the autumn season [1]. In 1986, he subsequently achieved the first serologically confirmed diagnosis of tsutsugamushi disease (scrub typhus) in Korea [2]. At a time when many patients had been misdiagnosed or left untreated, his work contributed to establishing a systematic approach to the diagnosis and management of systemic infections that can lead to acute kidney injury. Another important area of his research was hemorrhagic fever with renal syndrome (HFRS). He reported that the actual incidence of HFRS could be up to 11 times higher than previously estimated, a finding that contributed to improvements in the national infectious disease surveillance system [3]. In addition, he systematically investigated the pathophysiology of HFRS and contributed to the development of therapeutic strategies, playing an important role in improving patient outcomes and reducing mortality.

Professor Lee served as the 5th President of the KSN from 1996 to 1998, a period during which he strengthened the organizational capacity of the society and elevated its profile both domestically and internationally. He was a firm advocate for the KSN to evolve beyond a collegial assembly of physicians into a rigorous academic body with tangible public health impact. During his presidency, Professor Lee prioritized the improvement of the society's academic journal, the expansion of international scholarly exchanges—particularly within the Asia-Pacific nephrology community—and the standardization of dialysis facilities and training programs to meet the needs of the rapidly growing dialysis population in Korea. His leadership contributed to the advancement of Korean nephrology toward a stage capable of generating independent research and developing clinical practice guidelines.

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Professor Lee served as Dean of Seoul National University College of Medicine from 1998 to 2000, during which he contributed to educational reforms that supported the recognition of medical education as a scholarly discipline and the development of pedagogical methods, assessment tools, and faculty training programs. In addition, during his tenure as Director of the Central Research Laboratory at SNUH (1986–1990), he contributed to the modernization of the hospital's research infrastructure, supporting interdisciplinary research and facilitating the establishment of emerging programs, including the radioisotope laboratory.

Even in his later years, Professor Lee remained an avid learner, actively engaging with younger colleagues and advancing the field of nephrology. A pioneering figure in Korean internal medicine, he combined scholarly rigor with deep compassion, leaving a lasting impact through the generations he trained. His life closely paralleled the development of Korean nephrology. From practicing dialysis under conditions of limited medical infrastructure to advancing infectious disease research and transforming medical education, his contributions were both foundational and far-reaching. His leadership as President of the KSN and as Dean of Seoul National University College of Medicine played a pivotal role in shaping modern Korean medicine. The principles he upheld—integrating basic and clinical science, unwavering dedication to patients, and intellectual integrity—continue to guide the field. Though he has passed, the legacy he built endures as a lasting testament to his extraordinary service.

REFERENCES

1. Lee JS, Yoon SC, Lee HY, Ahn KR, Kim SK, Chi JK. Clinical features of the case identified as leptospirosis. *Korean J Epidemiol* 1984;6:47-51.
2. Lee JS, Ahn C, Kim YK, Lee M. Thirteen cases of rickettsial infection including nine cases of Tsutsugamushi disease first confirmed in Korea. *J Korean Med Assoc* 1986;29:430-438.
3. Kim YS, Ahn C, Han JS, Kim S, Lee JS, Lee PW. Hemorrhagic fever with renal syndrome caused by the Seoul virus. *Nephron* 1995;71:419-427. PUBMED | CROSSREF

https://doi.org/10.5049/EBP.2026.24.e4

Electrolytes & Blood Pressure (EBP; pISSN 1738-5997, eISSN 2092-9935), the official journal of the Korean Society for Electrolyte and Blood Pressure Research, is a peer-reviewed publication dedicated to advancing research in renal physiology, hypertension, and the cardiovascular system. The journal welcomes original research and reviews addressing glomerular filtration, tubular transport, hormonal regulation, fluid and electrolyte balance, acid-base homeostasis, blood pressure regulation, and toxin elimination. Topics of interest further include the renin-angiotensin-aldosterone system, renovascular and secondary hypertension, and hypertension-related kidney disease—emphasizing the complex interplay between renal function and cardiovascular health. *EBP* accepts contributions from researchers worldwide, across all related disciplines.

1. General Formatting Requirements

1.1. Online Submission

Manuscripts must be submitted electronically via the journal's online submission system at https://www.editorialmanager.com/ebp. Authors may track the progress of their manuscript throughout the peer review process. Revised manuscripts should be submitted through the link provided in the editor's decision letter and should not be submitted as new submissions. By prior arrangement with the editorial office, invited submissions may be emailed directly to: ebp@enbpr.org.

1.2. File Formats

Manuscripts must be double-spaced, include page numbers, and use International System of Units (SI). Acceptable file formats for the main text include Microsoft Word documents (DOC or DOCX). Submissions must include the following:

- Cover letter
- Main manuscript text
- Individual figure files
- Supplementary materials (if applicable, submitted as separate files)

1.3. Language and Style

Authors who are not native speakers of English are strongly encouraged to obtain professional language editing prior to submission. Abbreviations must be defined at first mention in the text, and non-standard abbreviations should be used sparingly.

1.4. Ethical Considerations

All research involving human participants, human data, or human biological materials must have received prior approval from an appropriate institutional review board or ethics committee. Manuscripts must clearly state the name of the approving committee and the approval number. Studies involving animals must also include ethics approval with a reference number. Manuscripts that include identifiable information (e.g., images, pedigrees) must be accompanied by signed informed consent from the subjects involved. Failure to provide adequate ethical documentation may result in immediate rejection.

1.5. Copyright and Permissions

Upon manuscript submission, the corresponding author must sign a license agreement on behalf of all authors, granting the Korean Society for Electrolyte and Blood Pressure Research the rights to publish the work. Authors are responsible for obtaining written permission to reproduce material previously published elsewhere, and such permissions must be submitted at the time of manuscript submission.

2. Manuscript Components

2.1. Cover Letter

The cover letter must include:

1) A statement of the manuscript's significance
2) Disclosure of any conflicts of interest
3) Confirmation that all listed authors have approved the manuscript
4) Confirmation that the manuscript has not been published or submitted elsewhere

2.2. Title Page

The title page should include:

1) Full manuscript title
2) Full names and affiliations of all authors
3) A running title (≤50 characters)
4) Designation and contact details of the corresponding author (mailing address, telephone, fax, and email)

2.3. Abstract

Abstracts for original and review articles must not exceed 250 words. Abbreviations should be minimized, and references should not be included.

1) **Original articles:** Abstracts should be structured under the following headings: Background, Methods, Results, Conclusions.
2) **Case reports:** Abstracts should be structured under: Background, Case Presentation, Conclusions.

2.4. Keywords

Four to six keywords should be listed alphabetically following the abstract. Keywords must be selected from the Medical Subject Headings (MeSH) thesaurus available at https://www.nlm.nih.gov/mesh/meshhome.html.

2.5. Main Text

The main body of the manuscript should be organized according to the type of article submitted:

1) Original Articles:

Reports of original research or novel methodology. Clinical trials must adhere to CONSORT/SPIRIT guidelines. Systematic reviews must comply with relevant reporting standards.

- Structure: Introduction, Methods, Results, Discussion
- Word limit: 4,000 words (excluding references, tables, and figure legends)
- Reference limit: 40

2) Review Articles:

Comprehensive and authoritative reviews, typically solicited but unsolicited submissions will be considered.

- Word limit: 4,000 words
- Reference limit: 50

3) Case Reports:

Reports of rare or novel clinical cases related to renal physiology or blood pressure.

- Structure: Introduction, Case Presentation, Discussion
- Word limit: 1,500 words
- Reference limit: 20

4) Letters to the Editor:

Brief communications, critiques of published articles, or concise case observations.

- Word limit: 800 words
- Reference limit: 8
- No abstract; max 2 figures or tables

5) Editorials:

Commentaries on articles published in the same issue or on broader topics of interest, typically commissioned.

- Word limit: 1,500 words
- Reference limit: 10
- No abstract; max 2 figures or tables

2.6. Acknowledgments

Acknowledgments should follow the main text and may include statements on ethical approval, funding, conflicts of interest, and author contributions.

2.7. References

References should be cited in-text using Arabic numerals in square brackets (e.g., [1]) and listed in order of appearance.

- List up to six authors. If more than six, list the first three followed by "et al."
- Journal titles must be abbreviated according to Index Medicus standards.

Examples:

- **Journal article:** Lee EK, Yang WS. Use of Fludrocortisone for Hyperkalemia in Chronic Kidney Disease Not Yet on Dialysis. *Electrolyte Blood Press* 2024;22:8-15.
- **Supplement:** Kim GH, Han JS. Therapeutic approach to hypokalemia. *Nephron* 2002;92(Suppl 1):28-32.
- **Online publication but not yet in print:** Chao CT, Kovesdy CP, Merchant RA. Sarcopenia, sarcopenic obesity, and frailty in individuals with chronic kidney disease: a comprehensive review. *Kidney Res Clin Pract* 2025 Jan 21 [Epub]. DOI: 10.23876/j.krcp.24.207
- **Entire Book:** Daugirdas JT, Blake PG, Ing TS. Handbook of dialysis. 5th ed. Wolters Kluwer; 2015.
- **Book chapter:** Verbalis JG. Hyponatremia and hypoosmolar disorders. In: Gilbert SJ, Weiner DE, Bomback AS, et al, eds. Primer on kidney disease. 7th ed. Elsevier; 2018. p. 68-76.
- **Website:** National Cancer Information Center. Cancer incidence [Internet]. National Cancer Information Center, c2009 [cited 2009 Oct 20]. Available from: http://www.cancer.go.kr/cms/statics

2.8. Tables and Figures

Tables and figures must be cited in numerical order.

- Table titles should be concise (≤15 words), with legends (≤300 words) placed below each table.
- Figure titles and legends should be provided in the main manuscript file.
- All non-standard abbreviations must be defined.
- Use superscript lowercase letters (e.g., ⋆, †, ‡) for table/figure notes.
- Figures must be submitted as separate files (not embedded), in high-resolution TIFF, EPS, or JPEG (≥300 dpi for color, ≥1200 dpi for line art).

2.9. Supplementary Materials

Supplementary files should be clearly labeled and submitted

separately using the "supplementary" designation. All supplementary materials must be cited in the manuscript (e.g., "Supplementary Figure 1").

2.10. English Editing Certificate

Non-native English speakers must upload a certificate from a professional editing service. Native English speakers should submit a placeholder file labeled "Certificate of English Editing (empty)."

3. Peer Review Process

Manuscripts are acknowledged within one week of submission. Submissions not adhering to technical standards may be returned without review. Each manuscript undergoes blind peer review by at least two external experts. Final publication decisions rest with the Editor-in-Chief.

4. Visual Abstracts (Optional)

Authors of original articles are encouraged to submit a visual abstract summarizing the study graphically. Visual abstracts may be used for online promotion and engagement.

5. Copyright

All accepted manuscripts become the property of the Korean Society for Electrolyte and Blood Pressure Research. A signed copyright transfer agreement must be submitted along with the manuscript.

6. Open Access Policy

All articles in *EBP* are published under a Creative Commons Attribution-NonCommercial-NoDerivatives License (CC BY-NC-ND 4.0), permitting unrestricted use, distribution, and reproduction in any medium, provided that the original work is properly cited, and no modifications are made. For commercial use, prior written permission from the Editorial Office is required.

7. Post-Acceptance

7.1 Proofs and Online Publication

Proofs are sent to the corresponding author and must be returned promptly. Substantial changes to content are not permitted at this stage. Articles are published online in PDF format and assigned a DOI. Final pagination is determined by order of acceptance for the biannual issue.

7.2 Article Processing Charges (APCs)

- Original/Review Articles, Case Reports: KRW 300,000 (Korea) / USD 300 (international)
- Letters to the Editor: KRW 100,000 (Korea) / USD 100 (international)
- Member Benefit: Fees are waived for corresponding authors who are active members of the Korean Society for Electrolyte and Blood Pressure Research.
- Invited Articles: Publication fees are waived.
- Waivers: Authors from low-income countries may apply for a waiver by contacting the Editorial Office.

The primary objective of peer review is to provide the editorial team with a scientifically informed, balanced, and evidence-based assessment of submitted manuscripts, ensuring that all editorial decisions meet the journal's rigorous standards. In addition, peer review should aid authors in improving their manuscripts, regardless of the final publication decision. Review reports recommending rejection should include a clear explanation of the manuscript's principal weaknesses, thus assisting authors in refining their work for submission to another journal if applicable.

1. General Information

Electrolytes & Blood Pressure (EBP) sincerely appreciates the time, expertise, and thoughtful input contributed by our reviewers. Reviewers play a critical role in maintaining the scientific integrity and academic quality of the journal. When feasible, reviewers are encouraged to assess revised versions of manuscripts they originally reviewed to ensure continuity and coherence in the evaluation process.

2. Confidentiality

2.1. Adherence to Ethical Standards

All peer reviewers must comply with the *Committee on Publication Ethics* (*COPE*) *Ethical Guidelines for Peer Reviewers*. This includes the obligation to:

- Maintain strict confidentiality with respect to manuscript content and peer review correspondence
- Refrain from using any part of the manuscript or information therein for personal advantage, or to discredit others
- Avoid sharing or disclosing any part of the manuscript before or after the review process

2.2. Communication with Authors

Reviewers must not contact authors directly under any circumstances during the peer review process. Any required communication should occur solely through the editorial office.

2.3. Authorship and Reviewer Contributions

Reviewers must not request authorship or suggest that they be added as co-authors at any stage. If a reviewer makes a substantial intellectual contribution that might warrant authorship, they must communicate this to the editorial office via a formal request outlining the exceptional circumstances. Breach of this policy will result in immediate rejection of the manuscript and potential sanctions.

2.4. Involving Others in the Review

Reviewers must not involve colleagues, students, or collaborators in the review process without prior written permission from the editorial office. If assistance is obtained with prior approval, the names and affiliations of those who contributed to the review must be disclosed, and proper acknowledgment will be recorded by the journal.

3. Conflicts of Interest

3.1. Identification and Disclosure

Reviewers must assess whether any conflicts of interest exist that could compromise the impartiality of their evaluation. Review invitations should be declined if any of the following apply:

- Recent collaboration with any of the authors (within the last 36 months), including co-authorship or ongoing submissions
- Shared institutional affiliation with one or more authors
- Personal (e.g., family) or professional (e.g., former advisors, mentees) relationships with the authors
- Financial interests that could be affected by the research findings
- Any other situation that may impair objectivity

3.2. Obligation to Report

Reviewers must promptly notify the editor or editorial office if any potential conflicts arise after accepting a review assignment. Failure to disclose relevant conflicts of interest may result in sanctions, including removal from the reviewer pool.

3.3. Impartiality and Fairness

Reviewers must remain unbiased and refrain from judgments based on authors' nationality, gender, institutional affiliation, religious or political beliefs, or other personal characteristics. The evaluation should focus solely on scientific merit.

4. Review Reports and Recommendations

4.1. Role of the Reviewer Recommendation

Reviewers are invited to provide a recommendation regarding acceptance, revision, or rejection. The editorial decision will be based on the review reports and the editorial team's judgment, and may not always align with individual reviewer recommendations.

4.2. Focus of the Review

Reviews should prioritize the scientific content of the manuscript

and its alignment with the scope of *EBP*. Minor issues related to formatting and stylistic conventions will be addressed by the editorial office and should not be the focus of the review unless they impede understanding.

4.3. Key Evaluation Criteria

Reviewers are asked to assess manuscripts based on the following:

- Relevance and significance of the topic to the field
- Originality and novelty of the findings
- Rigor and appropriateness of the study design, methodology, and analysis
- Transparency and reproducibility of the data, methodology, and interpretation
- Ethical integrity, including potential issues related to plagiarism, image/data manipulation, redundant publication, authorship disputes, or undisclosed conflicts of interest
- Clarity and quality of the writing, structure, figures, tables, and reference list

4.4. Constructive Feedback

Reviewers should aim to be objective, respectful, and helpful in their feedback. Comments should be specific, actionable, and framed in a professional tone. Authors should be guided toward improving their work, regardless of the final recommendation.
Suggested Review Structure

- General Overview: Provide a brief summary of the manuscript, including its objectives, main findings, and overall relevance. Comment on the significance of the study and its contribution to the field.
- Major Comments: Discuss substantive concerns such as study design flaws, inadequate data interpretation, lack of novelty, methodological weaknesses, or the need for additional experiments.
- Minor Comments: Address less critical issues such as unclear phrasing, inconsistent terminology, typographical or numerical errors, minor referencing concerns, and formatting of tables and figures.

We thank our reviewers for their invaluable service to *Electrolytes & Blood Pressure*. Our reviewers' expertise and commitment to rigorous peer review are essential to upholding the journal's standards and advancing the field.

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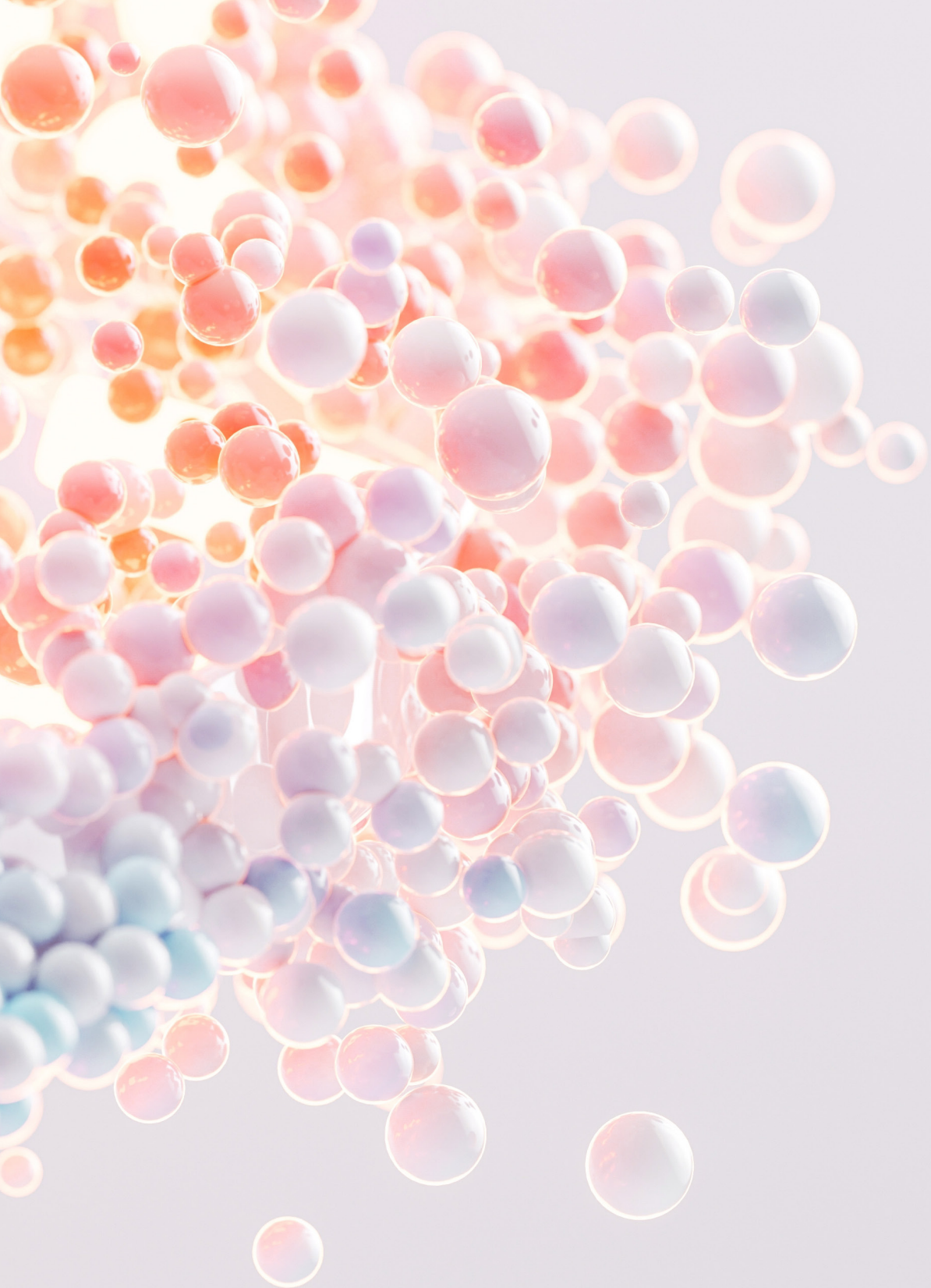

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