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INVITED EDITORIAL

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Moving ahead on the Kidney Health Initiative innovation roadmap, a transatlantic progress update

Kidney failure is a life-threatening condition affecting over 2.5 million people worldwide, with a doubling of that number expected by 2030.[1] Current kidney replacement therapies are limited to dialysis or transplantation. Dialysis can be done continuously (such as chronic ambulatory peritoneal dialysis) or intermittently multiple times per week (hemodialysis). Both dialysis options are expensive and limited in their efficacy as they cannot substitute all functions of the native kidneys. Hence, dialysis has a poor outcome and is still associated with high mortality rates. Furthermore, dialysis is demanding for patients living with kidney failure and has a significant impact on quality of life. In terms of kidney replacement, a kidney transplant comes closest to replacing the functions of the native kidneys, but there are by far not enough donor kidneys to treat all. And patients who do receive a donor kidney are exposed to the lifelong burden of taking immunosuppressive medication, thus, always facing the risk of transplant rejection.

Rational approaches to reduce the burden of end-stage kidney disease (ESKD) are prevention, and/or slowing the rate of progression. Mild kidney disease mostly goes unnoticed, whereas it significantly and independently increases the risk of cardiovascular mortality. Kidney disease has been described as *the most neglected chronic disease,* which calls for improved global partnerships for healthcare financing and regulation to improve patient outcomes, highlighting the need for innovation in this field.[2] Early detection and treatment of progressive kidney disease is key to reducing the need for kidney replacement therapies. But alongside prevention, there is also an urgent need to leverage innovations for kidney replacement in order to improve the quality of the treatment while containing the high costs. Worldwide, we urgently need progress for prevention and/or slowing progression, as well as for the development of alternatives to dialysis (as currently practiced) for the millions of people with ESKD who currently face a mortality risk worse than for most cancers.

Recognizing the huge need for innovations in kidney replacement therapy (KRT), the American Society of Nephrology (ASN) and the US Food & Drug Administration (FDA) established the Kidney Health Initiative (KHI), a public-private partnership that presently has over 100 member organizations and companies. In October 2018, KHI published a roadmap to spur innovation, particularly disruptive innovation, in KRT–previously also known as renal replacement therapy (RRT).[3] In 2019, KHI published an addition to this roadmap, regarding the management of fluid load.[4] These roadmapping activities form a catalyst for change.[5] The KHI roadmap is a dynamic ongoing process, and the roadmap itself is intended to be a living document, with periodic updates.

In parallel, the European Kidney Health Alliance (EKHA, uniting the voice of European Nephrologists, Nurses, Kidney Patients and Kidney Foundations) and the Dutch Kidney Foundation (DKF) also jointly had reached similar conclusions: The urgent need for more attention for kidney diseases, better prevention of kidney disease progress and disruptive innovations for better KRTs. Accordingly, a call to action was published by EKHA.[6] The DKF, being a member of both EKHA and KHI, published a research agenda stating that *Together, these initiatives form the basis for more cross-border cooperation between top international groups, between larger patient target audiences and among international funding agencies. This enables us to achieve much more than with national cooperation alone*.[7]

Early 2020, recommendations for an updated version of the KHI innovation roadmap were published, advising to synchronize the highly similar innovation plans of EKHA and KHI within an updated roadmap.[8] This periodically updated roadmap can be used as a tool to increase the yield and pace of innovation through "coopetition": A combination of collaboration and competition taking place in the context of a relationship, a business strategy, or a business model, in which parties compete and cooperate with each other at the same time. Roadmap-steered coopetition can also actively stimulate exchanges between the already existing worldwide structure of societies/associations of nephrologists, dialysis/transplant nurses and kidney patients, complemented by the existing worldwide structures of societies targeted at the development of artificial organs.[8]

This concept was further advanced by organizing two online interactive kidney-related innovation events in mutual transatlantic concordance, namely:

1. Invitational EKHA session on the *Need for Innovation in Renal Replacement Therapy (RRT)*, as a virtual side meeting of the 57th Congress of ERA-EDTA (June 9th, 2020), organized by EKHA, ERA-EDTA and DKF. This event is summarized in chapter 1.
2. Invitational ASAIO-IFAO Implantable Artificial Kidney (IAK) & Kidney Implant Developers NEtwork Worldwide (KIDNEW) session (virtual), as part of the 66th Annual ASAIO conference (June 12th, 2020). This event is summarized in chapter 2.

Figure 1 illustrates how these two events stimulate direct discussion between various existing well-organized "silos" of knowledge. Picturing a vertical mirror axis through the middle of Figure 1 reveals a strong resemblance between the ways EKHA and KHI are structured.

Due to the Covid-19 virus pandemic, both conferences canceled their physical gathering, but both innovation sessions on Kidney Replacement Therapies were reorganized to computer-based virtual meetings on the same dates as originally scheduled. In this article we provide a brief overview of both these meetings, plus web links to full-length video recordings of both.

1 | THE NEED FOR A CHANGE

On June 9th 2020 an invitational webinar on the need for innovation in Renal replacement Therapy was organized by EKHA and DKF.

This webinar was organized to encourage scientists, product developers and policymakers in Europe to work together to develop ground-breaking innovations in KRT. Ultimately, a worldwide consortium is needed to catalyze innovation, and therefore EKHA, DKF, and ERA-EDTA joined forces to strive for close collaboration with KHI and the various international societies for artificial organs, united within the IFAO. Table 1 lists the webinar program.

The program was professionally moderated by **Roderik van Grieken** of the Dutch Debate Institute, who first explained the "why and how" of the program and the electronic meeting tools.

In a short video, kidney patients **Wim Sipma** (The Netherlands), **Henning Søndergaard** (Denmark), **William Withers,** and **Fiona Loud** (both United Kingdom) told their stories and emphasized the long overdue need for positive

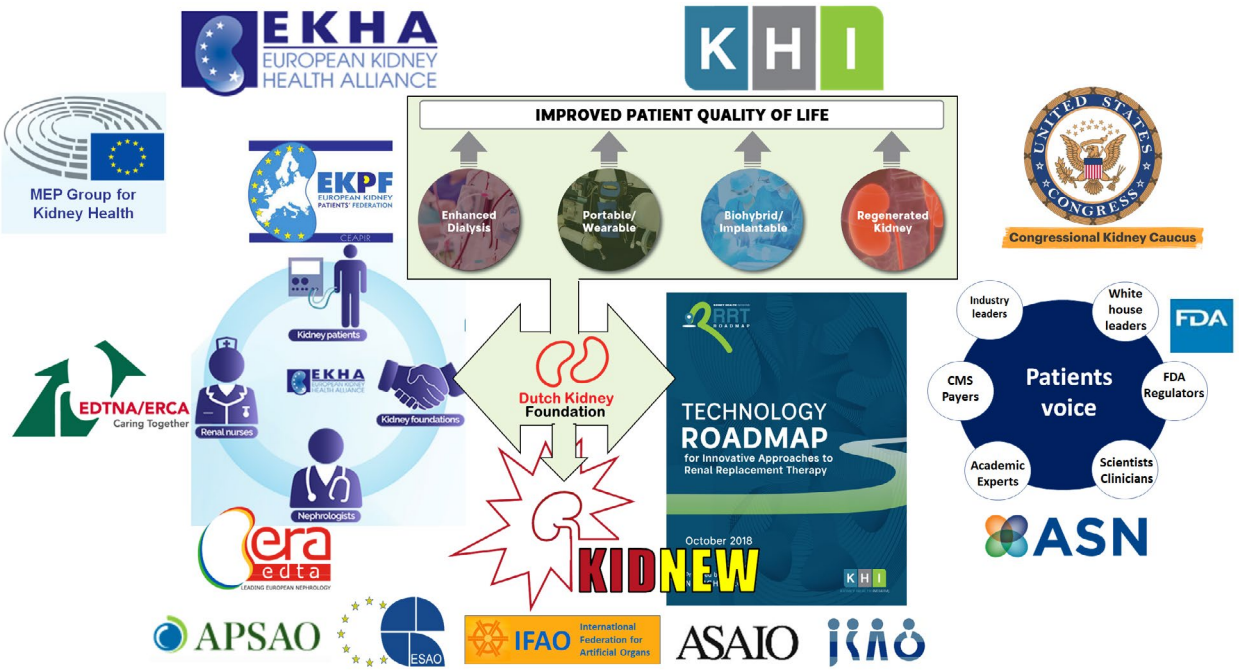

FIGURE 1 Currently existing organizational structures within the nephrology-related field: nephrologists, dialysis/transplantation nurses, patient associations, and kidney foundation from Europe (left) and the United States of America (right)–both supported by their respective political representatives (EU Kidney Health MEP Group & US Congressional Kidney Caucus)–as well as the established worldwide structure of societies for artificial organs (bottom row) could (via portable & wearable devices) coordinate efforts toward the ultimate goal of an implantable artificial kidney (IAK). KIDNEW aims to promote constructive interaction between all these parties to achieve this goal. The Dutch Kidney Foundation (member of both EKHA and KHI) helped to organize both meetings in a synergetic way [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Program of invitational webinar "The Need for Innovation in Renal Replacement Therapy," hosted by DKF, ERA-EDTA, and EKHA

Need for Innovation in Renal Replacement Therapy–Patients telling their story movie clock 00:03:08 Wim Sipma, Henning Søndergaard, William Withers and Fiona Loud
Double interview with prof Christoph Wanner (Chair ERA-EDTA) and Tom Oostrom (Director DKF) movie clock 00:09:39
The Burden of CKD: The Unbearable Lightness of Disregard movie clock 00:24:17 Raymond Vanholder, Chair European Kidney Health Alliance (EKHA)
An International Roadmap for Innovative Renal Replacement Therapy movie clock 00:53:00 Murray Sheldon, Associate Director for Technology & Innovation, FDA-CDRH
Cancer Lobby - Behind the Success movie clock 01:12:27 Anna Prokupkova, Advocacy & Project Manager, European Cancer League (ECL)
From a Portable to a Regenerated Kidney, a Moonshot Strategy movie clock 01:34:27 Clemens van Blitterswijk, Prof. University of Maastricht
The Crucial Importance to Involve the Patients movie clock 01:51:04 Norbert Lameire
A Vision on the future of Renal Replacement Therapy (connection lost, due to internet problems) movie clock 01:56:43 Jerôme Augustin, CEO NextKidney
Challenges to Meet for true Innovation movie clock 02:02:15 Mary Lou Wratten, Chief Medical Affairs Renal Division Medtronic Europe
Message from the Members of European Parliament (MEP) group on Kidney Health movie clock 02:06:14 Hilde Vautmans, Member EU Parliament & Chair MEP-group Kidney Health
Voting Results of the Break-out Session movie clock 02:16:07 Roderick van Grieken
Concluding Discussion movie clock 02:18:14 Tom Oostrom (Director DKF)

Note: Link to full video recording: https://www.youtube.com/watch?v=mppriCykios&feature=youtu.be. For each program section, the movie clock time where this section starts is listed.

change and disruptive innovation. Henning Søndergaard made a comparison between the speed of innovation in the dialysis sector and that in the telecom sector, by stating that if telecom consumer products would have advanced at the same speed as dialysis machines, his *mobile phone would be the size of 4 New York city blocks* in reference to the slow pace of innovation for dialysis machines. Although this comparison may be a bit oversimplified, it forms a good reminder that the field of kidney replacement technologies indeed innovates relatively slowly in comparison to many other MedTech areas.[8]

During a double interview, **Christoph Wanner** (Chair of ERA-EDTA) noticed an expansion toward more tailored treatments of kidney patients and exciting new pharmaceutical treatment modalities to largely postpone the need for dialysis onset, whereas **Tom Oostrom** (Director of DKF) highlighted the need for innovation (as also expressed by the patients movie) and the sobering estimation that by 2030 of the 14.5 million patients worldwide who then will *need* KRT, only one third actually will be able to *obtain* treatment. To achieve real progress, all stakeholders should work together. The DKF's NeoKidney initiative for the development of a portable artificial kidney and the Kidney Health Initiative are good examples of such multi-stakeholder consortia for kidney innovations. Fostering such consortia takes time, effort and money and is usually not possible without the support of the public and national governments. The speakers of the webinar all gave their recommendations on how to organize commitment for a strategic agenda in Europe and how to synchronize this internationally.

1.1 | Recommendation 1: Disease-related research in the EU should receive financial support that conforms with the burden of a disease and associated societal costs. Therefore, the nephrology community should request for more financial EU support

The nephrology community could do better in raising awareness among politicians and policymakers about the importance of kidney health for society. The first keynote speaker **Raymond Vanholder**, the Chair of the European Kidney Health Alliance (EKHA, that unifies the European associations of nephrologists, nephrology nurses, kidney patients, and kidney foundations) emphasized the lack of awareness throughout the population regarding the impact of kidney disease on patients and society. He illustrated this by a sobering comparison between the 5 years' survival from various cancer types versus that of patients needing dialysis or receiving a kidney transplant. In general, people are much more scared of "cancer" than of "dialysis" (although dialysis has worse 5-years survival than most cancer types). Significant progress has been realized in many cancer therapies, but innovations for KRT are lagging. Vanholder also stated that disease-related research in the EU should receive financial support consistent with the burden of the disease and it is associated societal costs, and therefore, the highly impactful, but so far neglected CKD would deserve more financial EU support.

1.2 | Recommendation 2: The EU should support aggregated data collection on frequency, healthcare costs, and costs due to loss of productivity because of CKD

The ERA-EDTA keeps a good registry of incidence and prevalence of ESKD. But data on healthcare costs and economic

burden of CKD and ESKD across multiple countries is still scattered. As part of a successful strategy, Vanholder suggests that more effort should be put into aggregated data collections on CKD, ESKD and their medical and socioeconomical impact.

1.3 | Recommendation 3: Expand the integration of diverse expertise

The second keynote speaker, **Murray Sheldon** (Associate Director for Technology & Innovation of the US FDA-CDRH USA) explained that KHI was founded by FDA & ASN, composed an innovation roadmap and is actively promoting research and product development. The cost of dialysis to the US Centers for Medicare and Medicaid Services (CMS) is becoming unsustainable whereas both life expectancy and the quality of life is poor. Kidney failure severely affects the lives of people and as reminded by Willem Kolff (inventor of dialysis) *If we are going to keep patients alive by artificial means, we then incur the responsibility to see that it is a good life and an enjoyable life*; which so far has not been achieved. An aspirational goal is the development of an implantable artificial kidney (IAK) by an international consortium and provided to people around the world free, as a worldwide humanitarian effort for peace. Much knowledge is already available throughout the world, but the scientific and engineering hurdles, as well as the financial risks for development of an IAK seem too large to be taken by a single party. Furthermore, we know that this problem also is not encountered by one country alone, it is worldwide and rapidly growing. Dr. Sheldon recommended to promote international cooperation between diverse types of expertise that are needed and to expand their integration to realize an IAK that can be made available worldwide.

1.4 | Recommendation 4: Focus on obtaining more funding for product development by engaging patient organizations (eg, cystic fibrosis or artificial pancreas as examples), and by seeking philanthropy

The vision of Dr. Sheldon is an international consortium that develops an artificial kidney that is provided to people around the world for free as a worldwide humanitarian effort for peace. Involvement of patients and philanthropy organizations (that do not depend on financial returns) is the key to success. The KidneyX initiative (a public-private partnership between the American Society of Nephrology and the US Department of Health and Human Services [HHS]) has helped to start a funding mechanism for kidney innovation in the United States. The initiative is patient-driven, with patient input incorporated in every project. The KidneyX program further recognizes patients-driven research through a patient innovators prize.

1.5 | Recommendation 5: Set your goals and formulate your political requests

A lot can be learned from the experience of the oncology community, which managed to get their topics on the political agenda. **Anna Prokupkova** (Advocacy & Project Manager of the European Cancer League) shared her experiences from the successful European cancer lobby, which delivered tremendous improvements in outcomes by generous funding, clearly demonstrating that serious investments in health do pay off. But to reach that point responsible policy makers must be convinced with clear evidence. Success needs: a powerful protagonist that keeps pursuing the goal (for the EU cancer case, this was Manfred Weber), the right break point to launch the topic, and strong support from citizens and all stakeholders, including industry. She further recommended to think strategically, define realistic goals and clearly formulate what to ask from politicians, and make sure that this falls within their mandate.

1.6 | Recommendation 6: Build a strong European Network

The success of a political lobby strongly depends on the relationship that you have with decision makers and stakeholders. Prokupkova stressed the prime importance of knowing the mandates of the people you try to convince. Make sure to be visible on the places where decisions are made, speak the same language and know what your stakeholders find important.

1.7 | Recommendation 7: Take part in ongoing initiatives

Within Europe there are many initiatives that address innovation and health issues, but very few of them will have a specific focus on kidney diseases. However, topics addressed by other disease networks may also be relevant for the kidney field, such as the medical device directive, or a new pharmaceutical strategy or the European health data space. Prokupkova advised to engage in these initiatives as well, also if they are only sideways related and make sure that kidney disease is mentioned in white papers and manifestos.

1.8 | Recommendation 8: Select a grand source of inspiration

In order to reach a large public, we should have an appealing story that is recognized by many. The last keynote speaker **Clemens van Blitterswijk** (Professor and Department chair of MERLN Institute for Technology-Inspired Regenerative Medicine at Maastricht University) stated *I'm absolutely*

convinced that the state of technology which we have today allows us to do a really good job, if we would focus our efforts and we'd have the budget available. Van Blitterswijk highlighted the great example of Dutch doctor/inventor Willem Kolff, who built the first working dialysis machine during World War II, and quoted him: *if we would spend the budget for one nuclear submarine on finding a cure for these people, they would no longer be dependent on dialysis*. It is this kind of analogies that make people appreciate the flagrant disparity of dialysis innovation.

1.9 | Recommendation 9: Go for an absolutely inspiring joined goal, while assuring that all participants also fulfill sub goals that are more important to them individually

Van Blitterswijk warned that it might be hard to disrupt a profitable business model such as dialysis, even if it lacks incentives for innovation and does not fully serve the demands of the people whose lives depend on it. The interests of as many stakeholders as possible should be included in your strategy, but alignment of all stakeholders may be a fallacy. Do not fear opposition and expect it to happen, as this is inherent to the innovation process (and especially for disruptive innovation).

The nine recommendations as put forward by the speakers are summarized in Figure 2 together with the outcomes of their discussion in 12 parallel breakout sessions, where they were ranked for priority by assigning 3, 2, and 1 points to three of the nine recommendations.

Both **Norbert Lameire** (University Hospital Gent) and **Mary Lou Wratten**, (Medical Affairs, Renal Care Solutions, Medtronic) were interviewed about the importance of engaging patients and the biggest challenges in innovation for RRT. The biggest challenge is not only the technology but to make something tangible out of it that meets the demands of the kidney patients. Lameire warns not to lose the essence in the translations; too often doctors tend to focus on reaching abstract outcomes such as improving phosphate clearance while this may appear irrelevant for many patients.

A prominent part of the meeting, highly recommendable to watch, was a speech by **Hilde Vautmans**, Chair of the MEP (Members of European Parliament) Group on Kidney Health, who emphasized her efforts in the European Parliament to get the European Union more actively involved with innovation for prevention of kidney disease and better kidney replacement therapy as the keys for a better and healthier life for their citizens, ending with a clear mission statement: *More awareness in Europe, more European funding, more innovation*. A direct link to this speech is: https://www.youtube.com/watch?v=fP-cmDZy7ac&feature=emb_logo

The event ended with a presentation of the outcome from the parallel breakout sessions (see Figure 2) and a concluding interview with Tom Oostrom, who expressed his hopes for improved cooperation and better funding for the fight against CKD and Kidney Failure.

2 | ASAIO-IFAO WEBINAR

For the 66th ASAIO meeting, the IFAO planned a special session on the **I**mplantable **A**rtificial **K**idney (IAK) and the **K**idney **I**mplant **D**evelopers **NE**twork **W**orldwide "KIDNEW." This session was organized in response to a request from Murray Sheldon, MD of the FDA on behalf of KHI. A major goal of

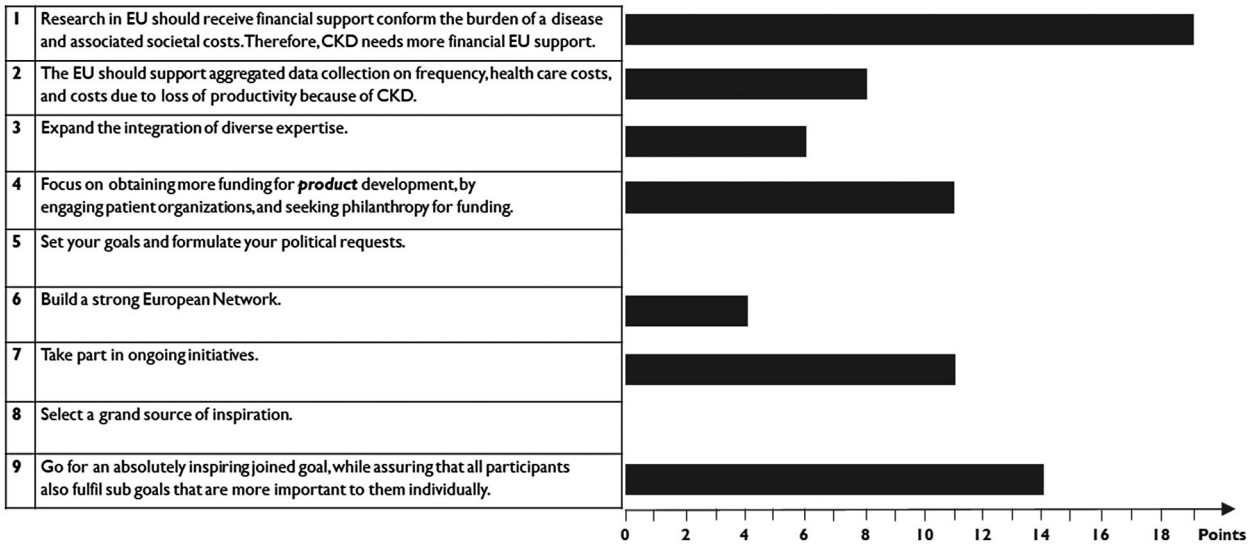

FIGURE 2 Recommendations as discussed during parallel breakout sessions and their resulting ranking. 12 discussion groups could each assign 6 points to 3 recommendations (3 highest, 2 medium, 1 lowest)

KHI is to encourage innovation in the treatment of patients with End Stage Kidney Disease, especially with radically new approaches which go far beyond the standard peritoneal or hemodialysis used widely today. An innovation roadmap for better kidney replacement therapies has been created by KHI to encourage innovative (and preferably disruptive) approaches to address patients' needs.[5] Although this roadmap is "agnostic" to the final form of kidney replacement therapy, the goal of an IAK is one of the most attractive eventual therapies, and a recurrent subject of presentations at ASAIO.

With the assistance of Murray Sheldon and Fokko Wieringa, a list was created of several of the laboratories around the world focusing on projects related to or directly aimed toward a workable IAK. Steve Ash sent out invitations, and from the response an impressive program was created (see Table 2).

Due to the Covid-19 pandemic, the in-person ASAIO meeting for 2020 was canceled. The IFAO and the organizers of the IAK "KIDNEW" Session, however, decided to hold a truly interactive session, with speakers presenting in real time and with live audio questions and additional audience feedback recorded in text via a chatbox. Technical hosting of the session was kindly provided by IMEC, in Eindhoven, The Netherlands. Steve Ash, Murray Sheldon and Fokko Wieringa were co-chairs. Members of ASAIO, ESAO, JSAO, and KHI comprised the audience, as well as several speakers and audience from a virtual ERA-EDTA Webinar regarding advances in KRT, held 3 days earlier on June 9th. Both sessions were advertised jointly, throughout the organizational networks of ASAIO, ESAO, JSAO, IFAO, KHI, ERA-EDTA, and EKHA. The presented combined progress was truly remarkable and showed tremendous potential:

Murray Sheldon opened the meeting with a vision to develop an implantable artificial kidney by an international consortium to be provided free to people around the world as a worldwide humanitarian effort for peace. He further explained the term *coopetition*: A combination of collaboration and competition taking place in the context of a relationship, a business strategy, or a business model. Organizations, firms and also geopolitical regions can practice coopetition. This could be an approach to speed-up the RRT innovation roadmap, which is also described within a recent article in *Artificial Organs*.[8]

The further speakers at the session presented new technologies for solving the numerous challenges of making an IAK capable of providing long-term and effective physiologic kidney functions, such as removal of uremic toxins, electrolyte homeostasis and fluid regulation:

Shuvo Roy showed results with hemofilters made from silicon wafers, successfully implanted in pigs with 90% patency up to 30 days, plus a working cell-based bioreactor, functioning for 3 days in a pig without inducing an immune reaction! Upon full maturation, this ultimately might lead to elimination of the need for immune system suppressing drugs that now form a risk factor for kidney transplantation. This approach gives hope that there eventually might be a way to surpass the best presently available therapeutic option.[9]

Jamie Hestekin showed a modular wearable artificial kidney (WAK) design (to be further miniaturized to IAK) using electrically steerable selective removal of Na^+, Mg^{2+}, K^+, or Ca^{2+} ions by electrodeionization, as well as selective removal of glucose by nanofiltration, and selective water transport by reverse osmosis.

Buddy Ratner presented selective photocatalytic oxidation of urea using TiO_2 nanowires, as well as STAR-polymer

TABLE 2 Program of ASAIO-IFAO "KIDNEW" session, hosted by imec

An International Roadmap for Innovative Renal Replacement Therapy
movie clock 00:01:45* Murray Sheldon, FDA, USA
The Kidney Project
movie clock 00:10:29 Shuvo Roy, UCSF, USA
Development of New Artificial Kidney Technology
movie clock 00:22:02 Jamie Hestekin, US Kidney Research Corp, UCLA & Univ. of Arkansas, USA
Ambulatory Kidney to Improve Vitality (AKTIV)
movie clock 00:31:17 Buddy Ratner, Univ. of Washington & Center for Dialysis Innovation, USA
The (Re)building a Kidney Consortium
movie clock 00:41:58 Iain Drummond, Mount Desert Island Biological Lab, USA
Implantable Blood Purification Devices
movie clock 00:50:33 Morteza Ahmadi, Qidni, Canada
Membranes for (Bio)Artificial Kidney Devices
movie clock 01:02:51 Dimitrios Stamatialis, University of Twente, Netherlands
Regenerative Medicine Crossing Borders - RegMed XB: The Kidney Moonshot
movie clock 01:10:57 Marianne Verhaar, Utrecht University Medical Center, Netherlands
Update on NeoKidney Consortium & KIDNEW
movie clock 01:21:26 Fokko Wieringa, IMEC & Dutch Kidney Foundation, Netherlands
Experiences from Semiconductor Roadmapping & Getting Disruptive Medical Technology Running
movie clock 01:33:22 Patrick de Jager, ASML, Netherlands
Wrap-up Discussion & Action Points
movie clock 01:45:23 Steve Ash, Fokko Wieringa, Murray Sheldon, Chairing panel

Note: The full video recording of this program can be viewed at: https://www.imec-int.com/en/connected-health-solutions/watch-the-video-of-the-kidnew-meeting-on-wearable-and-implantable-kidneys#video.

*For each program section, the movie clock time where this section starts is listed.

TABLE 3 Alphabetical list of used acronyms and what they stand for

Acronym	Description
ASAIO	American Society for Artificial Internal Organs
ASN	American Society for Nephrology. Co-founder of KHI
APSAO	Asian Pacific Society for Artificial Organs
CKD	Chronic Kidney Disease
CMS	Centers for Medicare and Medicaid Services. USA governmental organization that provides beneficiaries insurance coverage for most medical services and pays providers reimbursements for Medicare & Medicaid products and services. By law (1972), all people in the United Stated requiring dialysis or transplantation for ESKD are deemed disabled for purposes of Medicare coverage
DKF	Dutch Kidney Foundation
	Co-founding member of EKHA, and member of KHI as well
EDTNA/ERCA	European Dialysis & Transplant Nurses Association/European Renal Care Association
	Co-founding member of EKHA.
EKHA	European Kidney Health Alliance. Unifies ERA-EDTA, EDTNA/ERCA, EKPF, DKF, and 13 other kidney health-related organizations in Europe)
	EKHA advises the EU government on kidney health and related policies
EKPF	European Kidney Patients' Federation. Co-founding member of EKHA
	Unifies the various national EU kidney patient organizations
ERA-EDTA	European Renal Association - European Dialysis & Transplant Association
	Co-founding member of EKHA, and member of KHI as well
ESAO	European Society for Artificial Organs
ESKD	End-Stage Kidney Disease, formerly also known as End-Stage Renal Disease (ESRD)
FDA - CDRH	Food and Drug Administration Center for Radiological Health & Devices
IAK	Implantable Artificial Kidney
IFAO	International Federation for Artificial Organs
	Unifies ASAIO, APSAO, ESAO, and JSAO
IMEC	Interfaculty Micro-Electronics Center
	International not-for-profit R&D institute with headquarters in Leuven, Belgium
	Member of KHI
ISN	International Society for Nephrology
JSAO	Japanese Society for Artificial Organs
KIDNEW	Kidney Implant Developers NEtwork Worldwide
KHI	Kidney Health Initiative. Founded in the USA by FDA & ASN
	Public-private partnership including over 100 companies & organizations representing patients, care partners, health care professionals, industry, and US government
MEP	Member(s) of European Parliament
MMM	Mixed Matrix Membranes
NIH-NIDDK	USA National Institute of Health–National Institute of Diabetes and Digestive and Kidney Diseases
RAD	Renal Assist Device
RegMedXB	Regenerative Medicine Crossing Borders
UCLA	University of California Los Angeles
UCSF	University of California San Francisco
WAK	Wearable Artificial Kidney

material that induces no foreign body reaction and is fully symbiotic with human tissue, which enables vascular grafts with unprecedented low infection rates, as shown in animal tests. The technology is based upon interconnected bubble-like hollow rooms in the polymer, which allows colonization by human cells and is already CE-marked for human use in eye-drains (produced in Belgium).

Iain Drummond updated upon impressive progress made by the (Re)building a Kidney consortium on cell-lines, organoids, 3D-printing of nephron structures and a great data hub, while calling his role in the consortium as "the plumber" that connects all components.

Morteza Ahmadi updated on the Qidni device tested in a pig, which utilizes ultrathin nanoporous silicon membranes and a connection to the bladder.

Dimitrios Stamatialis presented his work on membranes for (bio)artificial kidney devices. He focused on the latest results related to the mixed matrix membranes (MMM) and to the renal assist device (RAD) containing kidney cells. The MMM, which combines filtration and adsorption, has high water flux, no albumin leakage and–in comparison to current dialyzer membranes–can achieve superior removal of protein bound toxins from human plasma.[10,11] Besides, the MMM acts as protective barrier for back transport of endotoxins from the dialysate.[12] The small scale RAD is built based on previous knowledge[13] and consists of "living membranes" based on a monolayer of conditionally immortalized kidney proximal tubule cells cultured on polymeric membranes. The cells can actively remove protein bound uremic toxins for human plasma in vitro[14] and have no allostimulatory effects.[15]

Marianne Verhaar gave an overview of the 250 million Euro Dutch/Belgian research consortium Regenerative Medicine Crossing Borders (RegMedXB), which works on regenerating kidney tissue, pluripotent stem cell (PSC)-derived kidney organoids and adult stem or progenitor cell (ASC)-based kidney tubuloids.[16] The RegMedXB consortium also develops intelligent, life-like materials, like supra-molecular materials that offer tunable properties and provide very promising results. RegMedXB also has interesting computational models to optimize molecular designs.

Fokko Wieringa provided an overview of the NeoKidney initiative from the Dutch Kidney Foundation (that also supports RegMedXB). The first step on their roadmap is now nearing completion with the launch of NextKidney (a portable sorbent-based hemodialysis machine), but an IAK is the ultimate long-term goal, which was the reason that the Dutch Kidney Foundation joined KHI and helped in writing the KHI roadmap (see also Figure 1). Wieringa also provided an example of how standards can help to boost innovation.[17]

The final speaker**, Patrick De Jager** showed us all the great progress made possible by numerous scientists and businesses in "coopetition" bound by an overall roadmap for progress, as for decades has been successfully practiced within the semiconductor industry, using Moore's law.[18] The financial risks for development of a next generation wafer stepper are simply too large to be taken by a single party. This is why the semiconductor industry works along a technology roadmap. De Jager also provided a real-world example of how he applied these roadmapping processes within MedTech, resulting in significant investment from a Belgium company to develop and realize production of isotopes for nuclear medicine, *without* a nuclear reactor. A real-world example of truly disruptive technology for medicine. De Jager furthermore pronounced the crucial need to involve industry.

The **concluding discussion** was characterized by a highly cooperative atmosphere: Offers were made to share cell-lines, for follow-up discussions on technical cooperation, the Dutch group in Utrecht needed a "plumber" to connect their cells, and was immediately offered help from Iain Drummond, while Daniel Gossett from NIH-NIDDK offered to provide an overview of dedicated calls for renal innovation, which he promptly did (this overview is also made downloadable via the ASAIO.org website). There was enthusiasm about witnessing that technological roadmapping *processes* from the semiconductor industry apparently can also be adapted and applied to stimulate innovation in Medical Technology. Moreover, also silicon wafer manufacturing *technologies* appear to be relevant for several presented approaches toward an IAK. This made the mixture of experts even more interesting.

The entire session, including presentations, the audience questions and speaker responses was videotaped. The lively two-hour session is available through a link provided by IMEC as hosting institution: https://www.imec-int.com/en/connected-health-solutions/watch-the-video-of-the-kidnew-meeting-on-wearable-and-implantable-kidneys#video or via the ASAIO.org website. We encourage our readership to watch it. All speakers at this ASAIO-IFAO IAK & "KIDNEW" session have been invited for an update-session during the 2021 ASAIO meeting in Washington, DC. It will be fascinating to see how much progress has been made by these very special and dedicated researchers.

To assist the reader, Table 3 contains an overview of all acronyms that are used in this article.

Fokko P. Wieringa[1]
Murray Sheldon[2]
Stephen R. Ash[3]
Thomas Groth[4]
Jasper Boomker[5]
Tom Oostrom[5]
Raymond Vanholder[6]

[1]*IMEC, Eindhoven, The Netherlands*
[2]*FDA-CDRH, Silver Spring, Maryland*
[3]*HemoCleanse Technologies, Lafayette, Indiana*
[4]*Martin Luther University Halle-Wittenberg, Halle (Saale), Germany*
[5]*Dutch Kidney Foundation, Bussum, The Netherlands*
[6]*European Kidney Health Alliance, Brussels, Belgium*

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AUTHOR BIOGRAPHIES

Fokko P. Wieringa (PhD) is Principal Scientist within the Connected Health Solutions Department of IMEC the Netherlands & part-time assoc. prof. of medical technology at Maastricht University. He works 32 years in MedTech and (co)invented 19 patents, is a core driver of the Dutch Kidney Foundations' NeoKidney initiative and co-author of the 2018 published Kidney Health Initiative (KHI) international innovation roadmap. He is heavily interested in Human Factor Engineering, interdisciplinary/translational R&D and represents the Netherlands for worldwide dialysis equipment standardization (HD & PD).

Murray Sheldon (MD) received his medical degree from the University of Michigan Medical School in 1975 and his cardiovascular fellowship at the Montefiore Hospital and Medical Center in New York. After practicing cardiac, thoracic and vascular surgery in Northern California for over 20 years, he entered the medical device industry, leading device development projects and providing expert consultative services to numerous start-up innovative medical device development firms. Dr. Sheldon joined the FDA in 2013 as the Associate Director for Technology and Innovation overseeing the Center's initiative to proactively facilitate medical device innovation to address unmet public health needs and to align what is traditionally done at FDA with what is required to support the US medical device ecosystem. His primary focus is working with FDA staff, the medical device industry, the clinical community and other stakeholders on ways to facilitate bringing innovative medical devices to the patients in the US first in the world. Dr. Sheldon currently leads the Medical Device Payer Communication Task Force, identifying methods to streamline the path from FDA approval to reimbursement.

Stephen R. Ash is a practicing Nephrologist at Indiana University Health Arnett in Lafayette, Indiana. He is CEO of HemoCleanse Technologies, Chairman of the Board of Ash Access Technology and co-founder of a number of spin-off biotechnology firms. Dr. Ash is a co-founder and Past President of the American Society for Diagnostic and Interventional Nephrology (ASDIN). He is Past President of ASAIO and served for 8 years as Secretary-Treasurer of IFAO. He is recipient of the Lifetime Achievement Award from ASDIN, the Celebration of Life Honor by NKF of Indiana, and the Lifetime Achievement Award from the Annual Dialysis Conference.

Thomas Groth is full Professor of Biomedical Materials at Martin Luther University Halle-Wittenberg, Germany with research interest in membrane development for bioartificial organs and modification of biomaterials for making cell-instructive surfaces for tissue engineering applications. Thomas Groth graduated in biology (MSc) and obtained his PhD in biophysics at Humboldt University Berlin, Germany. He did his postdoctoral thesis (DSc) at University of Potsdam in the area of biomaterials and biotechnology. He was former President of European Society for Artificial Organs and is now Secretary-Treasurer of the International Federation for Artificial Organs.

Jasper Boomker (PhD) is a biomedical scientist and Program Manager at the Dutch Kidney Foundation (DKF), a health charity that strives to improve the lives of kidney patients and to prevent kidney diseases. He helped setting up various public-private research projects on the development of wearable, portable and biohybrid artificial kidneys, new vascular access devices and regenerative medicine. He is also scientific advisor of Neokidney BV, a social enterprise that was initiated by the DKF for the development of a portable artificial kidney.

Tom Oostrom has been managing director of the Dutch Kidney Foundation since 2010. With the motto "Life comes first" the Kidney Foundation does everything to make sure that kidney patients survive and their quality of life improves. Tom Oostrom learned from practice: he started out as a nurse and later he studied policy and management in healthcare. His drive is to make a real difference for kidney patients, to help make their lives livable. This is necessary, because a renal disease is severe and makes a deep impact in someone's life.

Raymond Vanholder has been chairman of the European Uremic Toxin Work Group (EUTox) and Executive Board member and treasurer of Kidney Disease Improving Global Outcomes (KDIGO). Up till summer 2011 he was chairman of European Renal Best Practice (ERBP). Up till autumn 2014 he chaired the Renal Disaster Relief Task Force (RDRTF) of the International Society of Nephrology (ISN). He is past president of the European Society of Artificial Organs (ESAO) and immediate past president of ERA-EDTA. He is now retired (Prof Em at Ghent University) and president of the European Kidney Health Alliance (EKHA).