Vascular access hands-on training for young nephrologists: the fellows' experience of the N-PATH project REVAC module.

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ABSTRACT

Chronic kidney disease is a major public health problem, as population studies record a prevalence of 7.2% in individuals over 30 years and is expected to increase in the future. Many of them will end up undergoing hemodialysis treatment, and vascular access is not only an essential requirement for the technique, but also a determining factor in their prognosis; for all these reasons, every nephrologist should have both theoretical and practical knowledge of vascular access; however, the practical training is generally uneven and dependent on the hospital in which you train. It is within this context that the N-PATH (Nephrology Partnership for Advancing Technology in Healthcare) program was born with the objective of training 40 young European nephrologists in theoretical and practical aspects of Interventional Nephrology. To fulfill its mission, the 2-year program is composed of 4 modules of 6 months each including theoretical courses and hands-on training: Renal Expert in Molecular Pathology (REMAP), Renal Expert in Vascular Access (REVAC), Renal Expert in Medical Ultrasound (REMUS) and Renal Expert in Peritoneal Dialysis (REPED). By bringing together young nephrologists from all over Europe, the goal is also to create a strong network and promote Nephrology career at the European level. This publication highlights the experience of fellows who attended the REVAC hands-on training in Milan, focused on simulation and virtual reality for vascular access, and its impact on their nephrology training.

KEY WORDS

Vascular access training, nephrology residency, simulation-based training, virtual reality, N-PATH project.

1. Introduction

As a result of renal diseases, patients may require renal replacement therapy to substitute their kidney's function. Besides kidney transplant and peritoneal dialysis (PD), the most widely known method is hemodialysis (HD). In order to achieve a quality HD, the patient needs a well-functioning vascular access (VA). The creation and management of this VA in chronic kidney disease (CKD) involves a multidisciplinary team (composed of nephrologists, vascular surgeons, interventional radiologists and nurses) in which the scope of each member may vary among countries (1,2), as many complications are known to arise from this matter (3). After the *fistula-first* initiative in 2003 (4), the current trend is to involve patients and their experiences in a "shared decision-making process" (5), with the aim of providing "the right access, to the right patient, at the right time" (6). To reach this goal, the health care provider must be able to convey adequate theoretical and practical information to the patient, who may not have a clear understanding of medical terms and possible undesired outcomes of the procedure. Most European curricula cover theoretical knowledge in VA well; however, the organization of practical training is more uneven (1,7), even though training and experience have been shown to improve VA outcomes (7,8).

As Nephrology residents, trainees are taught the most "intellectual" aspects of the specialty, leaving the practical and interventional parts in the background of their curriculum. Learning how to place a temporary or permanent VA, perform a renal biopsy, or use ultrasound (US) machine will heavily depend on the hospital where the residency takes place, the attending doctor who oversees their education, and the quantity of patients attended throughout the day. Interventional procedures are therefore not considered part of the core of Nephrology training. However, the Nephrologist should be the coordinator within this multidisciplinary team and have total knowledge about the VA of their patients, especially if they undergo either acute or chronic dialysis treatment.

What could we do to fulfil the need for AV knowledge in the young nephrologists' training? It was already a controversial topic back in the 70s and 80s, when North American nephrologists had a solid understanding of the theoretical part of their specialty, whereas they were lacking practice at the interventional aspects of CKD, such as renal ultrasound (US) and VA management (9). Therefore, several training programs for trainees have already been implemented to develop VA skills (10,11). However, they are not usually meant for nephrologists, and only a few of those programs offer the opportunity to develop all techniques related to the spectrum of VA, as well as integrating them into a comprehensive practice to better achieve the goal of the right access for a specific patient. It is within this context that the N-PATH program is born.

2. Simulation and virtual reality as a new method of learning skills in medicine

Multiple factors will set the ability of a trainee to gain experience in VA creation. The volume of procedures is among the most important as if there is no one to practice on, the experience will not be acquired. However, patient safety is crucial and these invasive procedures can lead to serious complications. It is therefore necessary to ensure that they are performed in optimal conditions and by well-trained or at least well-supervised operators. To meet this need for high-volume and security, we believe that simulation-based training is probably one of the best ways to guarantee quality training with a high number of procedures in excellent safety conditions. Indeed, it only requires material resources such as an ultrasound machine and non-living model. As manikins and models are used rather than patients, this training method can also teach complications of interventional procedures. Thus, since simulation-training offers safety and the possibility of repeated trials, it allows an individual to perform multiple times the same procedure while not risking the well-being of a living patient. As a result, simulation-based training becomes increasingly prevalent in medical education (12).

For specialties besides Nephrology, simulation-training is a promising teaching method with is a growing clinical interest in its wider implementation on a variety of medical skills, even on already known procedures (13). For example, it has been well established for a while for surgical specialties. New surgeons can practice in realistic environments, get familiar with the surgical tools, with the feeling of different tissues and can perform the same procedure repeatedly to improve their technique with fail-safe attempts. In neurosurgery, plastic surgery, urology, and dermatology, virtual reality (VR) has been integrated into surgical and medical training, improving the quality of training, assisting in the decision-making process, and promoting a higher standard of health care (14-17). Non-surgical specialties have also demonstrated the benefits of simulation: Seam *et al.* demonstrate how ICU medical residents who were simulation-trained had fewer complications after inserting central venous catheter (CVC) compared to those who did not follow this training (12), while Ost *et al.* even showed how a simulated bronchoscopy improved real bronchoscopy performance, even if it was the first time on a living patient for the trainee (18).

From the Nephrologists' point of view, the gap between the anatomy knowledge needed for interventional procedures and its implementation in everyday practice could be covered using VR training methods. In Japan, Yokoyama *et al.* attempted VR simulation for guiding needle placement in a VA with success (19), whilst McQuillan *et al.* studied CVC insertion by nephrology fellows who received prior VR simulation-training, finding a significant improvement in their abilities (20). There is room for strengthening these results, but the advantages from VR simulation are no longer to be demonstrated. The concept of "see one, practice it hundred times in the simulation laboratory" is attractive based on confidence building and standardization which has been shown to improve the skills of the Nephrology fellows particularly in temporary hemodialysis catheter (THDC) insertion (21). Moreover, the results of a subsequent study of similar characteristics by Ahya *et al.* showed that nephrology fellows that completed simulation-based education displayed high levels of performance during THDC insertions on real patients (22). Three systematic reviews and meta-analyses evaluate the clinical outcomes of simulation-based education for vascular access. On the one hand, Ma *et al*. showed that this training improved learners' performance and decreased the incidence of pneumothorax (23). On the other hand, Madenci *et al*. and Hiromu et. al., both including two cohort studies different from each other, concluded that simulation-based education may improve overall success rates, although the reduction of adverse effects has not been demonstrated (24,25). It is important to mention that in these three studies not only the CVC were assessed as vascular access, but also peripheral inserted central catheters (PICCs) and arterial catheters.

Davidson *et al*. compared the training of professionals in high-risk areas, such as the airline industry and its current safety record in North America, with the training of health professionals and pointed out that the main difference lies in the preparation based on the crew resource management programs (26). In this regard, they propose a simulation-based training protocol with US-guided cannulation. Broadly, they developed a learning program which was divided in three stations: in the first station, trainees themselves are the subject of exploration using US; and in stations 2 and 3, parts of a turkey were used to train US-guided cannulation procedures.

Authors such as Pieterse et al. have even stated that simulation-training could even have a place in kidney transplantation. In a brief communication, they mentions that 360º VR glasses could address perioperative issues such as learning the patient's anatomy, anticipating possible ischemia injuries and adapting future immunosuppressive therapies (27), insinuating a new way of teaching young fellows that could break traditional education. On another aspect, Zgoura et al. used the VR simulator to train patients and health care workers in peritoneal dialysis, with a long-term aim to minimize the peritonitis rates (28). Davidson *et al*. also insist on group-training rather than individual-training, as communication skills courses have been shown to improve individual response to stressful situations. In this way, the experience will have a positive impact on the future trainee's attitude. It is clear that simulated clinical scenarios allow trainees to come up with decisions about the process and can be evaluated instantly as it occurs in a rather safe environment (29) among colleagues and committed mentors.

With those data, there is little doubt that VR and anatomical models will become increasingly more important in acquiring the skills for creating VA but, as of now, there is still room for improvement. Currently VR is of added value in understanding the anatomy, especially in three dimensions, but for developing actual surgical skills, it is lacking, as the controls are not approaching a life-like situation, and the hardware does not necessarily resemble surgical instruments. A step closer are the anatomical models: by creating veins and arteries with a 3D-printer, not only the appearance but also the tact approaches reality. However, some improvements can be made to those models, including flow in vessels, which could allow the use of Doppler techniques, and add other tissues such as skin, fat, bone, and nerves since learning how to handle these tissues properly to expose the vessels used to create the VA would be of added value. On this level, the use of animal cadaveric models is currently the closest to reality, for example in the placement of a CVC, it is also possible to use ultrasound-guidance. Even though they greatly contribute to acquire the basic skills for VA creation, some aspects are still not included in the simulation such as stress, time pressure, or the dependence of your aiding colleagues which are aspects that can only be found in real life situations. it is clearly demonstrated that real-life experience ("flying hours") is positively correlated with the success rate and durability of the VA and this is something to consider and add to future courses to allow trainees to learn in real situations but under adequate patient safety conditions.

3. N-PATH project

The Nephrology Partnership for Advancing Technology in Healthcare (N-PATH) is a European-wide advanced training course in diagnostics and interventional nephrology (https://npath.eu/) funded by Erasmus+ Knowledge Alliance, a European Commission program (http://www.erasmusplus.ac.me/). The course aims to improve knowledge and skills in Interventional Nephrology of the next generation of nephrologists from a multidisciplinary perspective at the European Union level. To achieve this goal, eight European medical Universities (*Amsterdam University Medical Centers* (UMC), *Università Degli studi di Bari Aldo Moro*, *Barcelona Parc Taulí Hospital Universitari*, *Ljubljana UMC*, *Maastricht UMC*, *Università Degli studi di Milano*, *University of Patras* and *General University Hospital in Prague*), two European medical societies (the *European Renal Association* (ERA) and the *Vascular Access Society* (VAS)) and two private partners experts in learning platforms and advanced simulation for training (*Eureka S.r.l.* and *Emac S.r.l. Tecnologia Vitale*) have joined forces to create a consortium leading this project. In August 2021, 40 young nephrologists (1st or 2nd year of nephrology training) from all over Europe were enrolled following a selection process. It consists of a 2-year course divided into 4 modules of 6 months each: *Renal Expert in Molecular Pathology* (REMAP), *Renal Expert in Vascular Access* (REVAC), *Renal Expert in Medical Ultrasound* (REMUS) and *Renal Expert in Peritoneal Dialysis* (REPED). The program is organized into e-learning sessions for theoretical purposes and hands-on training sessions which take place in a rotational module amongst the consortium organizations.

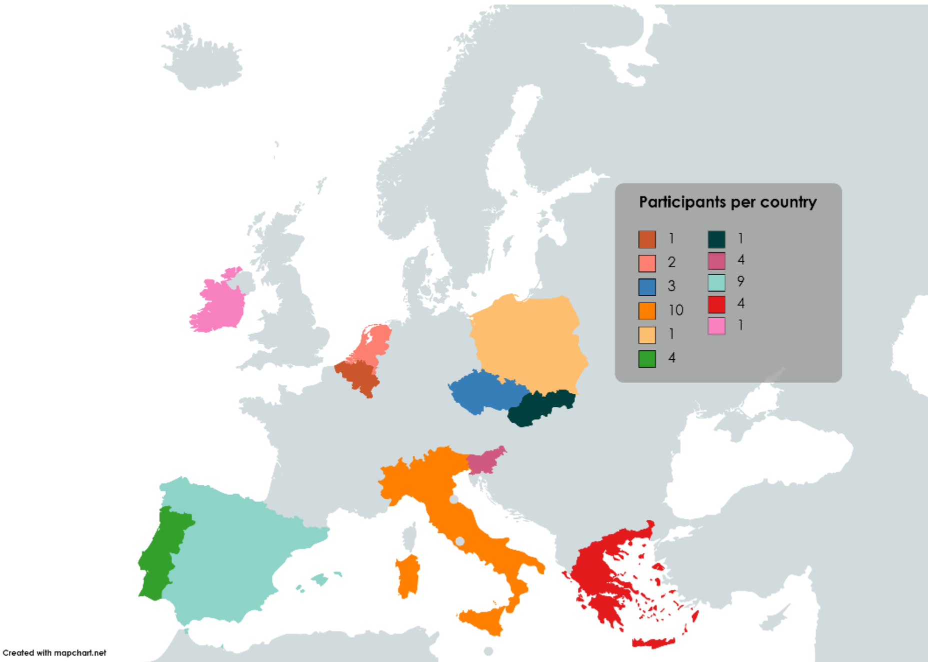

Figure 1. Countries of origin of the different fellows of the N-PATH program

As mentioned above, the course includes a module dedicated to VA that includes 15 e-learning lessons on the web platform (https://npath.eu/classes/revac/), covering a large number of topics; from the VA epidemiology to the construction and monitoring of surgical arterio-venous fistula (AVF) or graft (AVG) including the treatment of their complications, as well as percutaneous AVF and the management of CVC. Afterwards, a one-week hands-on training was held in 4 universities from the consortium (Bari, Milan, Maastricht, and Barcelona). This publication highlights the experience from the perspective of nephrology fellows attending the hands-on training in Milan from June 13th to 18th, 2022.

One of the objectives of this training was to address all the different resources available for the management of VA. First, AVF, whether surgical or percutaneous, AVG and CVC were introduced with video lectures and then discussed in a roundtable under the supervision of Professor Maurizio Gallieni and the participation of Professor Panagiotis Kitrou. Once these concepts were well assimilated, it was easier to approach the practical part in the simulation center recently created through the collaboration of the Veterinary Faculty (Prof. Fabio Acocella), the Physics department (Prof. Paolo Milani and prof. Tommaso Santaniello) and the department of Biomedical and Clinical Sciences (Prof. Maurizio Gallieni and Prof. Maurizio Vertemati) of the University of Milano. Prof. Vertemati's group illustrated a new virtual reality solution, developed in the framework of PrintMed-3D, which allowed gaining a newer and better perspective of the vascular anatomy, important for VA creation and its maintenance.
For the hands-on training, both synthetic and animal models were used. The artificial phantoms were designed and realized in partnership with PrintMed-3D (https://printmed-3d.com/en/news/next-generation-healthcare/) and the physics department of the University of Milano. The PrintMed-3D project was created with the intention of responding to the growing demand for personalized medical services in the clinical, diagnostic, and pre-clinical fields. Thanks to the development of new materials and the use of state-of-the-art printing technologies, it was possible to create anatomical models with mechanical and functional characteristics, like those of their natural counterparts. Thus, the REVAC N-PATH workshops allowed us to practice the surgical creation of AVF and AVG, the placement of ultrasound-guided CVC and their tunneling, and finally, the use of ultrasound-doppler, both for preoperative mapping and for postoperative monitoring of the maturation and maintenance of VA.

One of the key component for safety and improved outcomes in VA creation is the proper selection of the dialysis modality in a patient-centered approach, and it includes among other things: type of access, sites, the timing of the access placement. Another important issue is to evaluate the benefit-risk ratio on a case-by-case basis when confronted with a VA complication and thus decide to maintain it, salvage it, or abandon it throughout its clinical course. By addressing all these issues, we believe this course has fulfilled its role and it provides a solid foundation from which each young nephrologist can take benefit and improve VA management at their own medical center.
Besides the improvement on theoretical and practical knowledge, this small group-approach allows sharing of experiences, tips and tricks that only real-life practice can offer, especially in a group of doctors from all over Europe whose daily clinical practices may be different. Therefore, it allows to question certain habits and eventually to modify procedures for the benefit of our patients. Networking is probably the most valuable feature of this kind of project. Indeed, besides experiences shared during our sessions and courses, professional and friendly relationships have been forged between European nephrologists of the new generation. These can thus serve as a gateway to new projects in the field of VA, or other Nephrology-related contents as well.

4. Conclusion

From the N-PATH fellow point of view, the lectures and hands-on training of the REVAC module of the N-PATH project had a strong impact on our training and knowledge in VA. This module is an example of the teaching capacity of N-PATH and we believe that this kind of simulation-based training must be considered as a reference to formal training of Nephrology residency in Europe. Indeed, all the references mentioned in this paper shows that acquiring experience before real-life scenarios is key, as it has been clearly demonstrated to improve patient's safety and trainee's confidence. Therefore, we strongly recommend to continue promoting this type of initiative and pursue in this direction to improve the training of the future generation of nephrologists.

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