J Vasc Access 2010; 11 (00): 000-000 REVIEW

Simulation training for vascular access interventions

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ABSTRACT:
Training and learning in the field of access for dialysis, including peritoneal and hemodialysis and access for oncologic patients, is well suited for the use of simulators, simulated case learning, and root cause analysis of adverse outcomes and team training. Simulators range over a wide spectrum from simple suture learning devices, inexpensive systems for venous puncture simulation, such as a turkey breast or leg with a pressurized tunneled rubber or graft conduit, to sophisticated computer designed simulators to teach interventional procedures such as vascular access angiogram, balloon angioplasty and stent placing. Team training capitalizes on the principles used in aviation, known as Crew Resource Management (CRM) or Human Factor (HF). The objectives of team training are to improve communication and leadership skills, to use checklists to prevent errors, to promote a change in the attitudes towards vascular access from learning through mistakes in a non-punitive environment, to impacting positively the employee performance and to increase staff retention by making the workplace safer, more efficient and user-friendly.

Key words: Simulation, Team training, Dialysis access, Cannulation, End-stage renal disease, Crew Resource Management, Human Factor, Attitude

Accepted:

BACKGROUND

Dialysis access placement and maintenance require a complex coordination of people, systems, and technology. When functioning correctly, the system optimizes outcomes, including improved safety with fewer complications, decreased costs, and more timely and accurate diagnosis and treatment decisions. If systems are optimized, both patient and healthcare workers experience enhanced satisfaction.

High risk industries, most recognized being the airline industry, have been successful in realizing the safety benefits derived from specific training aimed to improve interactions between humans and systems. Concepts must be taught and understood and continuously updated and refined if optimal outcomes are to be expected. Implementation of human-system interactions involves change in the institutional culture. Changing institutional culture in the care of end-stage renal disease (ESRD) and dialysis access placement will induce significant outcome improvement. Effective complex systems emphasize three essential concepts: First, making systems and technology "user-friendly" in order for people to use them to enhance performance. Second, people must work and train together as a team and not act independently. This requires a culture change best defined by the term *interdependent thinking*. Third, in complex systems, the team of people assigned to use the system must practice and test the system <u>before</u> using them on patients.

Traditionally, healthcare learning, training, and testing takes place in unrealistic classroom settings, emphasizing knowledge based learning, ignoring the environment where the actual technology is implemented. These methods use target teaching of the individual away from the system in which he or she will be functioning. Another disadvantage of the current healthcare system is that new technology is never fully tested until a patient is involved. Imagine being a passenger if the airline industry functioned the same way! In fact, we in medicine have much to gain from aviation's past hard learned lessons (1). Almost everyone agrees with the concept of "doing better", ie quality improvement. There is much written, including workshop syllabi for courses on a variety of related improvement strategies, usually by institutional mandates (2). There are courses for improving leaders' personal communication skills (3). Many universities now teach credit courses in "*Conflict Resolution Techniques"*.

Recent research suggests that current methods of quality improvement efforts may not be effective in the evolving and increasingly technological medical specialties (2). Dialysis access in ESRD patients represents one example of this inadequate quality approach. The reason some individuals, certain institutions and societies and their projects are more successful than others was not well understood, until 2007, when the Nobel Prize in Economic Sciences was awarded to Hurwicz, Maskin, and Myerson. They shed light on success in businesses, stating that ***"The (our) best intentions for public good will go astray if the Institutional Arrangements are not consistent with the personal self-interests of the decision makers"***. These complex interpersonal relationships are more likely to be subliminally present in large organizations, such as state and government institutions (4). The fact that various members of the dialysis access delivery team are trained in isolation from each other exacerbates the detachment between the ESRD delivery system and the individual professional efforts. The team certainly never trains together with respect to deviations from expected defined outcomes. Therefore, faced with an actual dialysis access emergency, ie bleeding or other unexpected adverse outcome, the dialysis access team response is unpredictable and an optimal outcome is unlikely.

There are three important undesirable results of individual-focused dialysis access education. First, it is impossible to anticipate or understand the impact of technology, protocols, or administrative decisions on the healthcare delivery system. ESRD and healthcare governing bodies interactions, decisions, mandates and implementations are complex and cannot be accurately predicted when evaluated in isolation or in unrealistic settings (if they are evaluated at all before being implemented). Second, by targeting the individual, the system tends to blame a specific person for any adverse outcome, as opposed to improving safety in the system (5, 6). The loss of alignment between the individual, technology and the healthcare delivery system as a whole have not been adequately considered, reflected in the unrelenting growth of medical malpractice of the individual, usually the doctor. The current culture assumes that underlying medical malpractice ***"someone did something wrong and has to be responsible"***. Third, without being able to simulate the healthcare delivery system in a realistic setting, trying to identify weaknesses and implement improvements is hazardous, ineffective, and in most cases impossible.

The result is that governing bodies, both internal and external, try to improve outcomes by imposing regulations through protocols that have become increasingly complex. Protocols, although developed with the best intent, are never tested in a realistic environment and are, therefore, impossible to confirm as effective. The development of dialysis access protocols serve to define what the *individual* is supposed to do without regard to practicality and always without considering the interactions of the healthcare system and the patient. ***An example is an office generated memo by a middle level manager, who, in a multi-recipient addressed email, mandates that all central vein dialysis catheters must be removed after 90 days of placement. Usually these memos have an attached carrot and a stick in terms of recognition, i.e. in the monthly ESRD bulletin or a citation report to the regional ESRD network for protocol violation***. Enacting these types for protocols (mandates) makes the "blame the individual" response to poor healthcare outcomes unavoidable (5). Then, the current system of healthcare training and testing perpetuates the concept that outcomes rely upon the individual, as opposed to the system. Fear of failure and of reprisal for adverse outcomes is supported by this design; and therefore, the individual is dissuaded from identifying areas of healthcare system weakness and suggesting improvements. In the current system, suggestions for improvement (usually in the form of "incident reports") result in finding someone to blame, the unavoidable consequence of the existing, individual-focused system. To improve the outcomes of the healthcare system significantly, fundamental change in the education, training, and testing process must occur (5, 6).

The most important change needed is to move from focusing solely on the individual to emphasizing the individual's interaction with the entire ESRD and dialysis access system. This does not decrease or eliminate the individual's responsibility. In fact, it expects each stakeholder also to consider and take into account other teammembers' experience and expertise. The overall public good must prevail over the individual goals. However, this is a subject so complex that it took a Nobel Prize in ***Economic Sciences*** 2007, only to solve from a theoretical aspect (7, 8).

The anatomy of quality improvement in healthcare

For the past century the science of quality improvement has focused on the role of system or process function instead of only concentrating on individual training or competence. The early leaders in this movement realized that much improvement in quality and safety can be accomplished by customizing the processes or systems in which we work. This improvement can take the form of more efficient and predictable processes and more effective teams and communication as a method of ensuring quality and safety.

Medicine has typically focused on the craft or art of medicine and, some believe, largely ignored the importance of the process and team-dependent environment in which healthcare professionals practice. This heavy reliance has fostered the "captain of the ship" and "blame" cultures that exist in our profession.

Changing this culture has been particularly difficult in academic health centers where the tripartite missions of patient care, research and education foster the development of a culture dependent on the competence of highly trained practitioners, and minimizes the importance of the practice environment and teamwork needed for the highest quality and safe patient care. Many institutions have tried to change this culture by introducing methods of improvement and team building learned in other industries where errors can be catastrophic and costly in terms of human life and suffering. These methods are now being taught in the formal training of healthcare professions at various academic health centers around the country, such as the University of Texas System, and appear to be having a positive impact in changing the culture of those institutions, as evidenced by improving outcomes and a decrease in sentinel events.

Dialysis access simulation training

Simulation training is complex and requires for logistical (economic) reasons, a simulated dialysis access training environment to be an integral part of larger healthcare training facilities, commonly in a university or medical school teaching environment. Simulation centers allow for the teaching, training, testing and certification of every member of the dialysis access team in existing procedures of care, and for the development of new care paradigms, procedures, technology and devices *before* being applied to patients. The dialysis access simulation training course is designed so that participants will "dispel disbelief" by educating in realistic, reproducible situations, that directly translate to the actual dialysis access environment, such as the complete operating room or interventional suite, with all team members present in their real roles. The simulation center allows users to refine their skills, to identify potential problems, and to observe the outcomes produced in a realistic setting, including an emergency room, outpatient office, the operating room, and interventional radiology suites. The Dialysis access training staff includes representatives of all areas of the dialysis access team and experts in curriculum development. The dialysis access training curriculum includes customized (multi-level) curricula targeting distinct personnel categories as well as the entire team together.

The three basic components in dialysis access training are: 1. **Knowledge**, as "on line" reading material available, including ESRD background information, patient selection algorithms and indication for the mode, type and anatomic site, and describing dialysis access procedures by written text and images. 2. **Skills Training** includes concentrated short classroom learning with PowerPoint and video clips, testing and hands on learning under direct supervision in a simulation environment. 3. **Social Intelligence** (SI) training, in aviation referred to Crew Resource Management (CRM) of Human Factor (HF). These integrated training sessions will motivate the participants to align in a team effort, setting self aside and working for the public (patient) good, adopting an interdependent mindset. Patient and family actors are used when appropriate. Every simulation area is computer controlled with voice, video and data recording. Post-simulation debriefing includes review of the simulation (edited or actual time). Simulation examples and best practices can be delivered worldwide in person or by the Internet. Team training at the local level can take place using skills, techniques, and experiences taught at the center, reinforced and supported by the simulation center staff. The dialysis access simulation course supports the "train the trainer" concept, meaning that dialysis access expertise can be developed in the simulation center and then packaged into educational modules that can be delivered anywhere in the world.

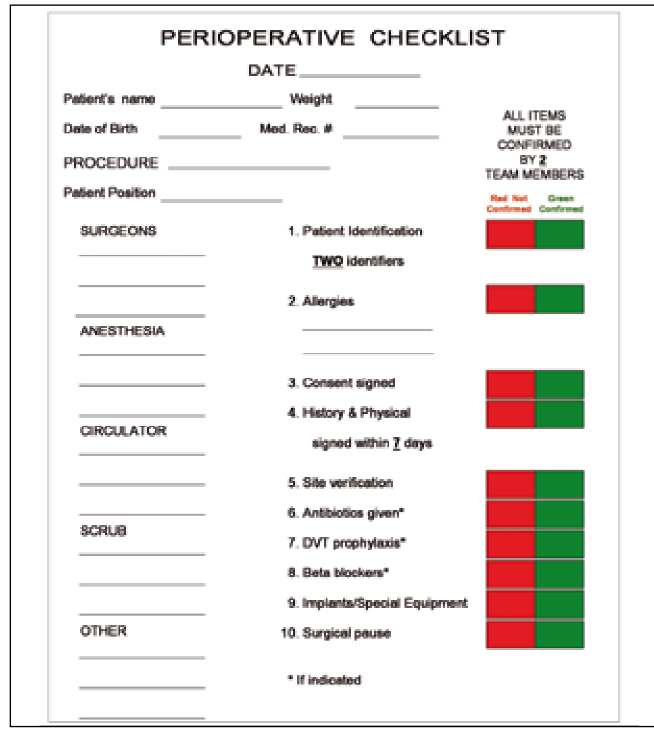
Lessons from the flight deck

Crew Resource Management (CRM) and Human Factor (HF) are acronyms used by airlines designed for safety training and educational systems for high risk industries. The basic concept and mission of these training programs are to reduce mistakes or errors resulting in safer and more efficient workplaces from fewer incidents and accidents. Simulation and simulators are vital components in aviation training. The program teaches that ***self-reporting*** of errors and mistakes or "near misses" be used to improve and correct system problems. Effective self-reporting requires a non-punitive cultural environment (5, 6).

One major airline has fully integrated the "Just Culture" process across their entire voluntary reporting system. Errors and procedural deviations are fed into the HF training on a recurring basis. They also have the ability to code scenarios from actual events into the flight simulators so that other crew members can be exposed and trained to prevent or mitigate future occurrences of critical errors. These proactive steps have resulted in a safer and more resilient operation. These best practices are also shared with other airlines around the world.

Stress, poor communication, the failure to identify and correct errors, and a culture of blame, often lead to undesired outcomes in the healthcare industry. Aviation addressed these same issues several decades ago, realizing that HF account for 70% of all aviation incidents and accidents. This led to the development of CRM or HF that trains multiple disciplines to work together in a coordinated and safety-conscious environment. CRM helped make commercial aviation the safest form of passenger transportation available today. With increasing awareness of

Fig. 1 - *Pre operative "Timeout" should be replaced with a "Briefing" statement by the surgeon or the perhaps better by the circulator nurse (1 A). As each airplane type has a different checklist that pilots go through for each flight, each access procedure will have specifics pertaining to site, instruments needed, expected problems (1B).*
Similar to cockpit checklists, the authors have detailed checklists for dialysis access procedures, so extensive requiring a separate publication.
Some checklists (such as patient demographics, allergies, antibiotics etc) are most effectively displayed in the operating room as wall checklists for everyone to see. An example of a wall checklist in depicted in Figure 2.


PERIOPERATIVE CHECKLIST

DATE ____

Patient's name ____ Weight ____

Date of Birth ____ Med. Rec. # ____

PROCEDURE ____

Patient Position ____

ALL ITEMS MUST BE CONFIRMED BY 2 TEAM MEMBERS

Red Not Confirmed / Green Confirmed

SURGEONS
1. Patient Identification
TWO identifiers
2. Allergies

ANESTHESIA
3. Consent signed
4. History & Physical signed within 7 days

CIRCULATOR
5. Site verification
6. Antibiotics given*

SCRUB
7. DVT prophylaxis*
8. Beta blockers*
9. Implants/Special Equipment

OTHER
10. Surgical pause

* If indicated

Fig. 2 - *This image is a generic example of an operating room checklist, where each critical item has to be switched from red to green before the procedure can begin.*

the similarities, these same concepts are now also being applied to other high-risk industries such as shipping, railroad, first-response, petrochemical and nuclear power industries. The healthcare sector lags severely behind in utilizing the often simple principles taught in CRM or HF courses. Simulation programs introduce CRM to medical facilities and hospitals to assist in the identification and management of errors. Highly interactive, multidisciplinary training in CRM and HF are co-facilitated by aviation and medical CRM experts and include reviews of aviation and healthcare incidents, accidents and sentinel events.

Participants will gain new understanding and acquire skills to improve communications. The training recognize signs of multiple, often hidden traps, usually referred to as the *Error Chain,* that when combined will cause an accident. CRM training emphasizes skills on how to communicate "uphill" in hierarchy structured workplaces and to recognize the value of briefings and debriefings (Fig. 1). Additionally, participants are trained to develop and use designed checklists (Fig. 2) for dialysis access procedures in the operating room and the interventional suite, as well as for needle cannulation of the access, and in the dialysis clinic for training personnel and patients.

Evaluations indicate CRM training programs influence personal behaviors that are known to reduce medical errors and improve the work environment (Tab. I). Perceived

TABLE I - DREYFUS SIX LEVELS OF MENTAL ACTIVITIES INVOLVED WITH DIRECTED SKILLS ACQUISITION/TRAINING

1. NOVICE (plays by the rules, low Situation Awareness (SA), no judgment)
2. ADVANCED BEGINNER (follows guidelines, some SA, "all things are equally important")
3. COMPETENT (some long-term vision, planning, feel accountable, standard routine procedures)
4. PROFICIENT (holistic views, priorities, decisions made easy, some intuition, perceives deviations from normal)
5. EXPERT (does not depend on rules, intuitive grasp of situation, analytic vision of what is possible; "I don't follow rules, I make them")
6. MASTER (the source of knowledge, looks for better and new ways, own unique style, likes surprises)

Adapted from: USAF: http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=ADA084551&Location=U2&doc=GetTRDoc.pdf

institutional cultural change lagged personal empowerment. Other ongoing patient safety initiatives may contribute to such findings.

Teamwork has greatly benefitted from simulation training (Tab. II). Technical and leadership skills can be taught and developed in less stressful situations, leading to better clinical performance and outcomes. For example, cardiac arrests are best taught in this setting rather than in the heated rush of a true code. The ability to stop and evaluate the situation, leads to better performance during the actual situations later.

Areas of current and future dialysis access simulation development

1. Computerized percutaneous intervention simulator

Training in percutaneous catheter-based procedures has become fragmented and variable in quality, largely due to the heterogeneity of proceduralists who carry out these procedures. For example, a given procedure (such as venous angioplasty) may be performed by a surgeon, interventional nephrologist, or an interventional radiologist or even a cardiologist. Given that each specialist has a different background, has probably trained differently, and garnered a different set of core competencies and skills, there may be wide variations in judgment and technique. Simulation of venous angioplasty, however, can provide a level of standardization in training, as well as metrics to assess judgment and technique. Ultimately, the experience on a simulator, coupled with end-of-case metrics can promote consistency and shift the physician to a higher level of competency. A number of simulators have been developed for arterial intervention, such as aortic endograft simulators. These simulators recreate the feel (haptics), visual fluoroscopic imaging, cardiovascular monitoring, and the procedural environment that a physician experiences during endovascular procedures. With appropriate proctoring and feedback during a series of endograft deployments, endovascular physicians can acquire skills leading towards the safe and effective clinical use of aortic endografts in patients. Currently, most certification pathways for use in proprietary aortic endografts require simulator training.

Arteriovenous hemodialysis (HD) access simulators are now being developed to recreate catheter-based procedures, and the first such simulator should be released before the end of 2010. This simulator will allow the operator to "treat" an arteriovenous dialysis graft stenosis. During the simulated procedure, the operator must access the graft, place a guidewire across the venous stenosis, select an appropriately sized angioplasty balloon, perform angioplasty, and finally deploy a suitably sized FDA-approved stent graft at the treatment site. Throughout the simulation exercise the operator will be supervised by a proctor, while making various decisions and technical maneuvers that will either lead to successful completion of the case or failure (with the opportunity to repeat the critical steps where errors were made). At the completion of the case, the operator will receive "metrics" that summarize performance during critical points throughout the case. The goal is not only to critique the technical skills of the operator, but also to train the operator to select and use a permanent implantable stent graft safely and effectively.

For example, carotid stenting (similar to HD access interventional procedures) is unique in having FDA requirements using simulation in the certification process to perform these procedures. ESRD patients' care and safety can also be impacted by these techniques and algorithms. New procedures can be performed on several of today's high fidelity systems and developed in that setting prior to progressing to direct patient care.

TABLE II - THE BENEFITS OF CRM TRAINING APPLICABLE TO THE DIALYSIS ACCESS TEAM

- Improving communication and leadership skills among all team members.
- Integrating checklists and error traps into everyday practice, reducing the risk of error.
- Promoting a culture supporting professional development.
- Improving employee performance and staff retention.
- Assisting to make working facilities safer and more efficient.

2. Simulation training to improve communication with patients

The importance of clear and effective communication in the doctor-patient and nurse-patient relationship is greatly underestimated. Basic professional communication skills are not learned despite 10 or more years of clinical work (9).

Compared to the airline industry, where communication within the team is the main focus of CRM, in the healthcare industry, at least two different settings are of crucial importance: among the healthcare personnel (in our case within the vascular access team) and in the nurse or doctor to patient interactions.

Participation in communication skills training courses focused on basic communication skills, as well as the handling of difficult situations in the doctor-patient interaction, has long-term benefits on both the clinical and personal levels (10).

In this perspective, an initiative began at Children's Hospital Boston in 2002, i.e. a series of 1-day educational workshops called the Program to Enhance Relational and Communication Skills (PERCS) (11). The aim of this program is to promote relational learning for healthcare professionals that integrates patient and family perspectives, professionalism and the everyday ethics of clinical practice. The starting point was preparing clinicians for challenging end-of-life conversations in pediatric and neonatal ICUs; the program then expanded to include a broad range of difficult conversations, such as helping parents during invasive procedures and resuscitation, and intervening with families in the aftermath of a medical error (12). The program features 4-hr workshops geared around the enactment of a case scenario by trained actors and participants. Each workshop enrolls 10-13 interdisciplinary participants. After each enactment, participants receive feedback by actors, other participants and facilitators on the challenging junctures of the conversation. Pedagogical principles include: creating safety for learning; emphasizing moral and relational dimensions of care; suspending hierarchy among participants; valuing self-reflection; honoring multiple perspectives; and offering continuity of the educational offering. PERCS seminars have been prospectively evaluated, with positive results (13). Similar training programs, based on small group role play sessions for improving communication skills, have reported successful outcomes (14). The advantage of simulating a conversation regarding a medical error, compared to learning how to do it in an actual crisis situation, is intuitive. Cultivating relational competence in healthcare should be an important goal in medical training, both before (15) and after graduation from medical school.

3. Problem based learning

Problem based learning is a form of simulation with discussion of cases in the mock situation of clinical problems and is highly effective. Simply reading about a clinical problem, the pathophysiology, and its various treatments is much more stimulating if based on a particular patient, even if the patient is factitious (16). Interaction without the threat of clinical misadventure is one of the greatest allures of simulation. Procedure based simulation is widely available in many medical communities. Training of individuals on simulators rather than on live patients is intuitive. It has been shown that this training has an impact on learning (1). Beyond education itself, simulation can also be used to judge the adequacy of training and is used for that purpose in some parts of the world.

4. Defined simulation based training protocols for learning ultrasound guided cannulation

Ultrasound use for central vein vascular cannulation in dialysis access is of paramount importance (17). Standardized training and experience is often lacking. *Ultrasound guided procedures teaching* emphasizes integration of three new attitudes: first, understanding the echo-graphic anatomy and image interpretation, including artefacts. Second, the trainee must develop confidence in image-mediated rather than eye-guided hand-probe motions and coordination between the hands moving in different directions, where the non-dominant hand directs the probe and the dominant hand performs the invasive procedure. Third, the trainee must attain confidence in handling the insertion device and tools, their parts and how to assemble it.

We have developed a strict, standardized ultrasound-guided inexpensive home-made simulator for cannulation of large veins as well as of dialysis access grafts and fistulas. The simulator consists of a turkey leg with an appropriately placed rubber tube, simulating the vein or the dialysis access. Each of ***seven teaching steps*** presents tasks of increasing difficulty. Ultrasound scanning and cannulation techniques are strictly standardized. This learning protocol allows for multiple attempts, ie learning by mistakes in a low stress environment. Currently, the ultrasound training entails three stations: 1. *Live real time large (neck) and small (peripheral) vein demonstration of vascular anatomy for cannulation*. 2. *Large vein needle cannulation using the seven-step teaching*. 3. *Dialysis access ultrasound directed cannulation training with a large 6-7 mm tube tunneled 3-5 mm below the turkey skin surface in a pressurized system filled with a red blood simulation fluid*.

The three distinct integrated levels of learning ultrasound-guided vascular access include:

a) understand ultrasound anatomy and correct image acquisition and interpretation (ultrasound semeiotics, artifacts etc);
b) attain operator confidence with image-mediated rather than eye-guided hand motion and coordination between hands working in different directions, with the non-dominant hand holding the probe obtaining the best ultrasound scan of the vessel, and the dominant operator hand holding the performing vessel puncture;
c) gain knowledge and confidence with the implanted device (how and when to insert and handle it, as well as how to assemble the single parts); the most effective learning process is based on the identification of the different phases such as better performance of trainees, standardization of teaching techniques, better qualification of tutors, reproducibility and exportability of the training model.

The authors propose a strict standardized skills session for teaching ultrasound-guided venous cannulation, divided in two phases as follows: a first phase of ultrasound examination training using healthy volunteers, and a second phase of a hands-on simulation utilizing an inexpensive home-made biological simulator.

During the **ultrasound examination phase on healthy volunteers**, the trainee will gain skills in:

- Familiarity with the ultrasound device settings and;
- Proficiency in correct image acquisition;
- Identification and interpretation of ultrasound artefacts;
- Recognition of the venous and the arterial blood vessels and relevant anatomic structures such as PTFE (polytetrafluoroethylene) grafts, muscles, nerves, thyroid and pleural line;
- Knowledge of anatomic variation;

- Ability to perform CUS (compressive ultrasound) to detect thrombosed veins.

In addition each trainee, by using B-mode ultrasound, will attain the following skill-sets:

- Create a **transverse scan** of the internal jugular vein and common carotid artery, and then, by letting down the tail of the probe, obtain a visualization of:
- The confluence of the subclavian and internal jugular veins;
- The brachio-cephalic vein.
- A **longitudinal scan** of the subclavian vein, using the supra-clavicular approach.
- **Transverse and longitudinal scans** of the infraclavicular vessels (axillary vein and artery). During the visualization of the brachio-cephalic vein and the subclavian vein by supraclavicular approach, the trainee will learn to:
- Identify the pleural line appearing as a hyper-echoic line characterized by the sliding sign.
- Perform transverse scans of the brachial vessels above the antecubital fold at the elbow. Each trainee must be able to visualize (1) brachial artery and veins, (2) the basilic vein, by moving the probe medially, and then, moving the probe laterally to the brachial artery, finally (3) the cephalic vein.

The practical session is based on a step-by-step approach to the skills that the trainee must progressively achieve. **These "Seven Steps on a Healthy Volunteer" include:**

1. Transverse scan of the internal jugular vein (IJV) and common carotid artery along their course.
2. Transversal scan of the IJV just above the clavicle and tilting the probe:
    - Step 2a: obtaining a visualization of the confluence between subclavian and internal jugular veins, subclavian artery and the identification of the pleural line;
    - Step 2b: correct longitudinal scan of the brachio-cephalic vein.
3. Move the probe laterally to obtain a longitudinal scan of the subclavian vein and the identification of the pleural line.
4. Correct ultrasound imaging of the axillary vein and artery:
    - Step 4a: transverse scan of the axillary vessels;
    - Step 4b: longitudinal scan of the axillary vein by 90° clockwise probe rotation.
5. Transverse scans of the brachial artery and veins.
6. Transverse scan of the basilic vein, by moving the probe medially.
7. Transverse scan of the cephalic vein by moving the probe laterally to the brachial artery.

The **hands-on simulation with the biological vascular access model** consists of performing several ultrasound-guided punctures of a vein or a dialysis access.

This phase of the practical session is also structured on a step-by-step approach towards the skills that the trainee will progressively achieve: these **"Seven Turkey Steps"** use an easy-to-make, inexpensive simulator consisting of a turkey thigh, with a rubber tube inside, filled with colored fluid, simulating blood under pressure (Fig. 3 A-D). The seven steps, divided in three phases, are summarized below.

PHASE 1 – ULTRASOUND IMAGING INCLUDE 3 STEPS

Step 1. Probe orientation and correct acquisition of the transverse scan of the simulated vessel.

Step 2. Hand stabilization, static and dynamic evaluation of the vessel:

- Step 2a: the ulnar side of the hand rests on the phantom surface to avoid probe slipping;
- Step 2b: evaluate the diameter and depth of the vein;
- Step 2c: test vein compressibility and probe sliding to evaluate any change in venous depth and course.

Step 3. Shift to long axis scan of the vein, the "short axis" vein image is centered in the screen, 90° clockwise probe rotation until a longitudinal view of the vein is reached.

PHASE 2 – ULTRASOUND GUIDED NEEDLE MANIPULATION INCLUDES 3 ADDITIONAL STEPS

Step 4. Static visualization of the needle and its tip in the "short axis" and "long axis" view. Scan the phantom's soft tissue to identify the needle (no needle manipulations in this step).

Step 5. Dynamic visualization of the needle and its tip without venous target. The trainee manipulates the needle (introduction and extraction) within the phantom soft tissue under close ultrasound guidance (pay no attention to venous target in this step).

Step 6. Techniques of ultrasound guided venipuncture. First, by obtaining a transverse scan of the vessel, competency in achieving the "in plane" and the "out of plane" puncture techniques is established:

- Step 6a: The "out of plane" technique is achieved by centering the target vessel in the middle of the screen in its short axis so that the midpoint of the transducer becomes a reference point for the puncture site. The needle is directed perpendicular to the probe plane. Tissue motion during ultrasound-guided puncture helps to direct the advancing needle prior to visualization of the needle itself. Performing this technique, the needle will be detectable only when it enters the vein as a hyper-echoic track;
- Step 6b: the "in plane" technique is performed by advancing the needle in a plane aligned with the long axis of the transducer, which should center over the vessel in its short axis. Using this technique the needle tip and shaft will be completely visualized along its course so that the operator will have total control of its trajectory;
- Step 6c: the trainees will now be able to perform the "in plane" technique by using a longitudinal ultrasound imaging of the vessel.

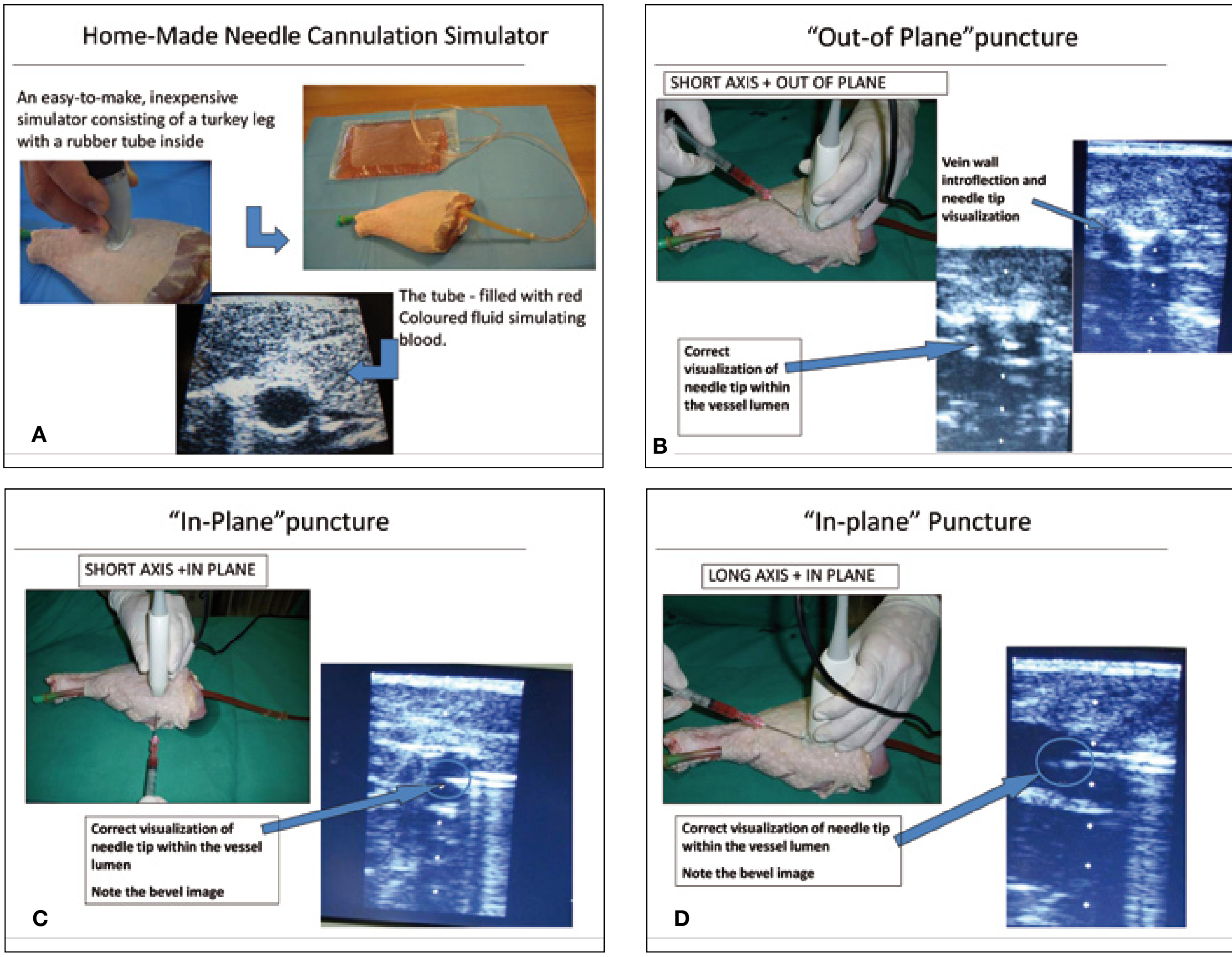


Fig. 3 A-D - *The dialysis cannulation simulator consists of a turkey leg with a rubber tube 5 mm under the skin surface producing a realistic image of a PTFE graft (3A). Figure 3B depicts the "out of plane" ultrasound technique with images, Figure 3C and 3D outlines the "in plane" technique with visualization of the entire cannulation needle.*

PHASE 3 – CATHETER INTRODUCTION IS THE FINAL AND 7TH STEP

Step 7. Complete simulation of field preparation, catheter introduction, securing and medication and ultrasound visualization of catheter within the lumen.

5. Root cause analysis of adverse surgical outcomes

Simulation is commonly used for *root cause analysis* in high performance industries, but has not been widely applied in analyzing adverse medical outcomes. Determining root causes of adverse medical outcomes could substantially improve safety. The authors have developed a simulation method for root cause analysis of adverse surgical outcomes (18). Plaintiff and defense expert opinions of medical and legal records from 631 closed surgical claims were analyzed. Not all closed case claims contained enough data to model in a simulation environment. Certain presumed root causes such as communication errors and medical decision paradigms are most appropriate for simulation. One case of *delayed recognition* of a post-operative complication resulting in death was chosen as a pilot case. The presumed root cause in the closed case claim simulated in this study was lack of communication of a critical laboratory value. Essential data was abstracted and a paper and electronic medical record developed, appropriate participants were chosen, the simulation scripted, and an environment was chosen to model the actual events. The scenario was tested four times. Two of the four simulations we performed duplicated the adverse event; in the other two participants responded to the scenario in a way that would have avoided the adverse event. Review of the simulation revealed the root cause was not the lack of communication and the discovery of the abnormal laboratory value as initially postulated, but it was determined to be individual judgment of the meaning of, and response to, the abnormal value. The authors suggest that simulation is a powerful tool for root cause analysis of adverse outcomes and should be further tested and used as a training tool in the selection of the best mode, site, and type of dialysis access. Corrective measures based on root cause simulation can be developed and implemented to minimize the potential risk for recurrence and improve patient safety.

As a component of CRM training, each dialysis access team member should have a basic understanding of all aspects of dialysis access procedures performed. ESRD patients often have complicated medical histories, and an involved, invested team is the key to success. Methods to increase a feeling of personal investment include ensuring that each team member understands the procedure and each step involved in the procedure. For example, in the operating room, the surgeon should understand and be able to demonstrate a general knowledge of tasks of the circulating nurse and surgical scrub technicians. Each team member should understand every aspect of the model/task at hand even if they will not be directly performing those tasks. This is not to take anything away from the team member that normally performs this task, but as a safety check, to ensure that the correct steps are being followed in every procedure every time. In the operating room, the surgeon, the anesthesiologist, the circulator nurse and scrub technician must all understand the steps in a particular procedure. The surgeon should be able to start the electrocautery devices, know instrumentation including the details of suture material and where to find them. Not only does this ensure that the procedure goes smoothly, more importantly, this will impact how the team handles the difficult case with unforeseen complications. When every member of the team understands the entire procedure *and* their role in the case, individuals are more likely to become invested in the project (procedure, etc) and lead to higher quality outcomes.

Disruptive behavior training. Simulation training also lends itself to teaching providers how to deal with emotionally stressful situations that often complicate already difficult clinical situations. Actors portraying disruptive physicians, ancillary staff members, or even patients, can be used to simulate how these behaviors can negatively impact patient outcome in the ESRD patient care environment. Additionally, these simulations can be used to teach providers how to react in a productive and in a non-confrontational manner that diffuses the stressful situation, rather than worsening an already intense (and tense) case. Simulating how team members and individuals will react to disruptive behaviors is important, as most individuals and teams perform reasonably well in ideal situations; however, the reality is that often cases are less than ideal and human nature is unpredictable in the untested situation. The focus on provider reaction to disruptive behavior comes at a time where hospital administrators are increasingly aware of the negative impact of disruptive healthcare worker behavior on patient care outcomes and disruptive individuals are faced with harsher repercussions.

Credentialing issues. Procedural based simulation is widely available in many medical communities. Training of individuals on simulators rather than on live patients is intuitive. It has been shown that this training has an impact on learning (19-24). Beyond education itself, simulation can also be used to judge adequacy of training and is used for that purpose in some parts of the world.

In general, providers currently prove their ability and competency through indirect routes (oral examinations) or through supervision of skills (proctored activities, for example, number of cases for approval for specific procedures). As models become more realistic, simulation of actual clinic situations can and should be used to ensure a provider's skills and competency. For example, the American College of Surgeons has taken initiatives to ensure trainees currently in residency programs are able to perform basic laparoscopic skills through the Fundamentals of Laparoscopic Skills Program (22). In 2004, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) launched the Fundamentals of Laparoscopic Skills (FLS) program; the program is co-sponsored by the American College of Surgeons (ACS) and is now required by the American Board of Surgery (ABS) in order to take the written boards (25, 26). In 2006, the ACS established a program for accrediting Education Institutes, in hopes of raising the standards for surgical skills education and to foster collaboration. In 2007, the ACS in conjunction with the Association of Program Directors in Surgery (APDS) launched a national skills curriculum, which established standardized curricula across a wide breadth of surgical tasks, procedures, and environments (25). In 2008, the RRC in Surgery mandated that all residency programs must have a technical skills curriculum for accreditation. Proof of FLS certification is a requirement for subsequent application for Board Certification as well as for privileges for trainees in terms of performing laparoscopic procedures (19, 20). Simulation is likely to induce new paradigms for certification and credentialing. While these processes have not been fully developed, the ABS Maintenance of Certification (MOC) program has instituted requirements for surgeons to evaluate their performance in practice (23, 27). While simulation has not yet been formally adopted by the ABS for the MOC program, such practices may prove useful and valid in the future. In addition, dialysis access procedures simulation training will eventually be extended to credentialing.

CONCLUSIONS

Simulation is the mainstay for training of all dialysis team members and access systems before being applied to patients. Simulation in medicine means many things to many people. The penetration of simulation techniques into medicine varies across specialties and applications. Although some think of simulation as purely a surgical tool, it clearly means much more.

The dialysis access training curriculum includes evaluation, testing and training of dialysis access delivery and to stimulate technological progress, in a realistic manner, considering the entire ESRD system and all team members. The emphasis of the simulation is to improve measurable outcomes with a focus on the system interfacing with the individual. The future impact of dialysis access simulation is yet to be determined. Resources are required to incorporate new technologies. In the fee-for-service medical environment, institutions will have to sort out how best to integrate and prioritize resources (28).

Conflict of interest: AA: PLEASE COMPLETE.

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REFERENCES

1. Leape LL. Error in medicine. JAMA 1994; 272: 1851-7.
2. Thor Johan. Getting Going on Getting Better. How is Systematic Quality Improvement Established in a Healthcare Organization? Implication for Change Management Theory and Practice. Thesis for Doctorial Degree (PhD) 2007. Karolinska Institute, Stockholm, Sweden. ISBN 978-91-72357-274-3.
3. Goleman D, Boyatzis R. Social Intelligence and the Biology of Leadership. Harvard Business Review September 2008.
4. Vaughan D. The dark side of organizations: mistake, misconduct, and disaster. Annu Rev Sociol 1999; 25: 271-305.
5. Dekker SWA. Just culture: balancing safety and accountability. Aldershot: Ashgate Publishing Co, 2008.
6. Dekker S.W.A. Laursen T. From punitive action to confidential reporting: A longitudinal study of organizational learning. Patient Safety and Quality Healthcare 2007;4(5): 50-56
7. The Prize in Economic Sciences 2007 • The Royal Swedish Academy of Sciences • www.kva.se
8. Hurwicz L. Optimality and informational efficiency in resource allocation processes. In: Arrow KJ, Karlin S, and Suppes P, eds. Mathematical Methods in the Social Sciences, Stanford University Press. 1960.
9. Aspegren K, Lønberg-Madsen P. Which basic communication skills in medicine are learnt spontaneously and which need to be taught and trained? Med Teach 2005; 27: 539-43.
10. Finset A, Ekeberg Ø, Eide H, Aspegren K. Long term benefits of communication skills training for cancer doctors. Psychooncology 2003; 12: 686-93.
11. Browning DM, Meyer EC, Truog RD, Solomon MZ. Difficult conversations in health care: cultivating relational learning to address the hidden curriculum. Acad Med 2007; 82: 905-13.
12. Lamiani G, Meyer EC, Browning DM, Moja EA. Between science and suffering: difficult conversations in healthcare. Recenti Prog Med 2009; 100: 239-46.
13. Meyer EC, Sellers DE, Browning DM, McGuffie K, Solomon MZ, Truog RD. Difficult conversations: improving communication skills and relational abilities in health care. Pediatr Crit Care Med 2009; 10: 352-9.
14. Bylund CL, Brown RF, di Ciccone BL, et al. Training faculty to facilitate communication skills training: development and evaluation of a workshop. Patient Educ Couns 2008; 70: 430-6.
15. Shapiro SM, Lancee WJ, Richards-Bentley CM. Evaluation of a communication skills program for first-year medical students at the University of Toronto. BMC Med Educ 2009; 9: 11.
16. Yoo M. A case of bleeding access. J Vasc Access 2010; 11: 00-000.
17. Kopman D. Ultrasound-guided internal jugular access. Chest 2007; 132: 302-9.
18. Korndorffer JR, Rennie K, Garstka ME, Slakey DP. Root cause analysis of adverse surgical outcomes using simulation. http://tulane.edu/som/sim/research/upload/Rootcauseabstract.pdf. accessed September 8, 2010.
19. Ahmed K, Keeling AN, Fakhry M, et al. Role of virtual reality simulation in teaching and assessing technical skills in endovascular intervention. J Vasc Interv Radiol 2010; 21: 55-66.
20. Fundamentals of Laparoscopic Surgery: http://www.flsprogram.org/. Accessed August 24, 2010.
21. Peters JH, Fried GM, Swanstrom LL, et al. Development and validation of a comprehensive program of education and assessment of the basic fundamentals of laparoscipic surgery. Surgery 2004; 135: 21-7.
22. Scott DJ, Dunnington GL. The new ACS/APDS Skills Curriculum: moving the learning curve out of the operating room. J Gastrointest Surg 2008; 12: 213-21.
23. Scott DJ, Ritter EM, Tesfay ST, Pimentel EA, Nagji A, Fried GM. Certification pass rate of 100% for fundamentals of laparoscopic surgery skills after proficiency-based training. Surg Endosc 2008; 22: 1887-93.
24. Scott DJ. Patient safety, competency, and the future of surgical simulation. Simul Healthc 2006; 1: 164-70.
25. American College of Surgeons (ACS) Program for the Accreditation of Education Institutes. http://www.facs.org/education/accreditationprogram/index.html, accessed August 24, 2010.
26. The American Board of Surgery. http://home.absurgery.org/default.jsp?index, accessed August 24, 2010.
27. Scott DJ. Proficiency-based training for surgical skills. Semin Colon Rectal Surg 2008, 19: 72-80.
28. Friedell ML. Starting a simulation and skills laboratory: what do I need and what do I want? J Surg Educ 2010; 67: 112-21.