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## ORIGINAL ARTICLE

# ON SITE PORCINE KIDNEY TRANSPLANT SIMULATION TO PREPARE A NOVICE TRANSPLANT CENTER FOR HUMAN LIVING KIDNEY TRANSPLANT

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## ABSTRACT

***Introduction:*** *The Ethiopian kidney transplantation program was recently established. Except for the transplant surgeon most professionals involved had little experience on kidney transplantation.*
***Objectives:*** *To evaluate if simulation with a porcine helped develop the ability of the new kidney transplant center for human living donor nephrectomy and recipient kidney transplantation.*
***Methods:*** *A review of the reports of the transplant surgeon, nursing and anesthesia team and in-depth interviews of all involved in the swine simulation was performed at St. Paul's Hospital Millennium Medical College in Addis Ababa. Additionally, a self-administered questionnaire was used to collect data on individuals' perception of the simulation*
***Results:*** *Four simulations sessions were performed on five pigs in three months. There was a month gap between each session. In the first three sessions one swine was utilized for each encounter, while in the last session, two swine were used. With each session, new issues or problems were identified, but the skill and understanding of the team improved steadily. Successful nephrectomy, back table perfusion, and successful allotransplant was achieved by the fourth session. At the end of the fourth simulation, many gaps and areas were identified for focus prior to initiation of human transplant. Everyone involved perceived simulation as important and recommended such an approach in similar settings.*
***Conclusions.*** *The experience, the knowledge and skills gained from porcine living donor and recipient transplant simulations were significant. We recommend using such simulation to test a new service in a new center. Simulation sessions need to be performed until the team gets comfortable and all gaps are identified.*
***Key words:*** *swine, simulation, surgical skill, test, Ethiopia*

## INTRODUCTION

End stage renal disease (ESRD) is considered as Africa's forgotten disease (1). This is because, despite an increase in the incidence and prevalence of the condition, the attention given by health authorities is limited (2). Kidney transplantation is the preferred treatment option for ESRD patients in terms long term survival and quality of life (3). But due to the nature of the disease, complex immunological interactions, and the patients' condition, transplantation demands highly trained professionals.

The list of professional needed for successful transplant, includes surgeons, competent anesthetists, operating theater nurses, ICU nurses, etc....

It also demands special surgical and non surgical supplies, which must be in place before the living donor can be placed at risk and the kidney transplanted (4). Due to these requirements, all forms of renal replacement therapy in most part of Africa, including Ethiopia, often have been inadequate, and are largely centered in the big cities (1,5). In 2013, St. Paul's Hospital Millennium Medical College (SPHMMC) located in Addis Ababa, Ethiopia began collaboration with University of Michigan with the goal of establishing kidney transplant services in Ethiopia. With the support of the Ethiopian Federal Ministry of Health, specialists from the University of Michigan began regularly traveling to Ethiopia to identify services and supplies that would be required and to advise on the development of a kidney transplant program at the hospital.

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In order to provide an optimal environment for kidney transplant care, a hotel building was renovated specifically for transplant care to include all the basic services a transplant center would need. These needs were determined to include operating rooms for the donor and recipient near each other, a four bed ICU, wards for donors and recipients, etc ... Additionally, other preparations were also made: designing the transplant program and protocol, training transplant operating theater nurses (on basics of laparoscopic surgery equipments and living kidney transplantation theater nursing), basic exposure on kidney transplantation to the fellows abroad (assisted few open donor nephrectomy and transplantation and observed laparoscopic donor nephrectomy), short term training to a transplant nephrologist, a pathologist and a radiologist. Materials and instruments for performing donor nephrectomy and transplant were also secured.

Despite the exhaustive preparations, it was still unclear if the team was up to the challenges of removing a kidney from a healthy human being, and successfully transplanting it to their loved one. It was therefore decided that trials utilizing a porcine model would be undertaken to test if the center was ready for human patients. The objective of this study was to evaluate if testing the ability of the new kidney transplant center to transplant a porcine kidney can help in preparation for beginning human living laparoscopic donor nephrectomy and transplantation.

## MATERIALS AND METHODS

A mixed qualitative and quantitative study was done from April to July 2018 of the original participants in the porcine simulations to evaluate if testing a new transplant center's capacity with swine kidney transplant simulation helps in identifying and filling gaps for beginning human living donor nephrectomy and transplantation. The transplant center is located at SPHMMC in Addis Ababa. Preparations for first kidney transplant took almost three years. In the last few months (April to June 2015), four sessions of swine transplant simulation were done on five pigs.

Review of reports of the transplant surgeon (mentor) which he wrote at the end of each simulation session was used as source of data. Each simulation session was also evaluated critically by in-depth interview of key informants (the transplant surgeon, the four transplant fellows, two anesthesiologists, five operating theater nurses). The process of evaluation of performance was done by interviewing the lead transplant surgeon who was in practice for more than 25 years in kidney transplant surgery. Performance and achievements at each session was described in a narrative and with pictures. Additionally, a self- administered questionnaire was used to collect data on each individual's perception of the simulation sessions.

Ethical clearance was obtained from SPHMMC IRB.

## RESULTS

A total of four simulation sessions were done on five pigs under a senior transplant surgeon from University of Michigan leadership. After each session, debriefing was held with all team members and a list of things learned was drafted. A total of 12 individuals were interviewed and completed the questionnaire. Below are findings of the reports and interviews.

***Achievements and Decisions at Each Simulation Simulation: – I (Swine #1)***

The swine was obtained from a local farm and transported to the transplant center after sedation. The animal was not weighed formally, but the estimated weight exceeded 80 kg (Figure 1). Intravenous access was obtained by insertion of a venous cannula in a superficial vein that was visible after shaving the animal's ear. Anesthesia was given by a veterinary surgeon and anesthesiologists. As the swine upper airway anatomy can be difficult for endotracheal intubation, tracheostomy was performed while the pig was supine under ketamin sedation. An endotracheal tube was used for the tracheostomy to align with the swine airway anatomy and sutured in position for airway control.

**Figure 1:** Swine #1 positioned for hand assisted laparospcopic nephrectomy. Notice the size of the pig.

The animal was put on its right side for left nephrectomy. It was noted that the animal was too large for the instruments, which simply would not reach the kidney through the laparoscopic ports. The operation was terminated without completing the nephrectomy. The team nevertheless gained significant and valuable experience because it allowed us to check all the devices necessary, including laparoscopic suction, harmonic scalpel, laparoscopic ports, CO2 insufflators, and instruments. It was also learned that the ambient light in the operating room was too bright for the images on the monitor to be seen clearly.

The hand port came from a different supplier compared to what the experienced faculty had used in the past. Unfortunately, the port did not function as expected, resulting in significant CO2 leakage and poor intra-abdominal visualization. It was also noted that the ports that were available would not admit the laparoscopic stapler that would be used to divide the renal vasculature. After completion of the procedure we did a debriefing.

***Lesson learnt***

The natural room light was too bright, and a plan was developed to address that issue. The weight of the pig was too much, so the need to have a swine weighing 30-40kg was established. The purchased hand port needed to be changed or additional information was needed to be obtained from the supplier on its use. Everyone felt the lesson learnt in the process was enormous in terms of operating room management, surgeons, anesthesia and nurses understanding regarding what is needed and what needs to improve. A decision was made to repeat the simulation with a smaller animal.

***Simulation session II (Swine #2)***

***Nephrectomy:***

This time, the swine procured was a more appropriate size (approximately 35-40kg). The veterinary care and process of placing the pig under anesthesia was smooth, and similar to that described in simulation session I. Technical issues with the hand port were overcome after consultation with the supplier's representative. Laparoscopic ports were checked and their size was correct for instrument passage. Pneumoperitoneum was established uneventfully. The operation initially went reasonably smooth, but eventually required conversion to open due to bleeding from the liver. Appropriate laparoscopic packs were noted missing, which could have improved the outcome, as control of blood loss would have been easier. Though converted to open, both the artery and vein were divided using GIA staplers, and kidney was recovered successfully. The lack of TA stapler shortened the artery to half its normal length. The bleeding was likely related to a combination of laparoscopic inexperience and the fragile nature of the porcine liver.

***Perfusion***

Sterile normal saline kept in a deep freezer was carefully slashed, opened sterilely and manually for use as sterile ice slush. The kidney was perfused with cold normal saline. Appropriate vascular cannulae were noted lacking. Perfusion was done through regular IV cannula. Thought it was very slow cooling of the kidney on the back table, perfusion was successfully performed (Figure 2).

**Figure 2:** Perfusion of the Swine Kidney at the back table

***Attempted Transplant***

Transplantation of the kidney was attempted into the right lower quadrant of the same pig. A Bookwalter fixed retractor was used, but it was discovered that some critical components of the retractor were either not available, or were not compatible with the model purchased, and this made exposure challenging. During the transplantation, the pig was hemodynamically unstable due to the blood loss from the nephrectomy and the consequence of supine ventilation, which swine tolerate poorly as the time period of ventilation extended. The operation was terminated after the venous anastomosis, without completing the transplant as the pig no longer had a palpable blood pressure in the iliac artery. It was also noted that many of the instruments that had been obtained specifically for vascular anastomotic work were of inadequate quality. In contrast to the donor operation, the operating lights were not bright enough, and adjustability was limited due to the ceiling height of the operating room. During the attempted implantation of the kidney the electric power failed. It was restored after approximately 3-5 minutes.

***Lesson learnt***

The swine size was appropriate for the intended purpose. The need for right stapler for the artery, laparoscopic packs, and gentile manipulation of the swine was better understood during the nephrectomy. It was realized that better vascular cannulae were needed to perfuse the kidneys. In the attempted transplantations we learnt the appropriateness of the Bookwalter retractor and its elements, the quality of the vascular instruments bought assessed (we need better quality and finer forceps, scissors, and needle drives).

In addition, the need to have a backup generator and headlights was emphasized, as the donor laparoscopic surgery portion was completely dependent on adequate electricity. We also learned doing the nephrectomy and transplant in the same pig may not be ideal, although it was more economical.

***Simulation Session III (Swine #3)***
***Nephrectomy***
The nephrectomy on swine #3 demonstrated integration of the previous sessions' lessons and went well. Blood loss was minimal. We found that the lack of an endo-TA meant the artery was shorter than it could have been. This time, the major issues was the backup generator, which cycled off and on once activated as that it was providing too much power, causing the safety features of some of the equipment to shut itself down.

***Perfusion***
Perfusion of the kidney was successful, but as in simulation session II, the lack of appropriate cannulae was a problem that limited the ability to cool the organ in a timely fashion.

***Transplant***
Transplant was again attempted on the same pig. Despite minimal blood loss, the pig was again in extremis at this point. It was realized that the problem was the physiology of the animal model which does not support prolonged anesthesia and ventilation in a supine position. Similar problems noted with swine #2 due to the instruments and the retractors were also present. It was also problematic that there was bleeding in the pelvis. This would have been a minor problem, except that adequate suction was not available. The venous anastomosis was again performed successfully, but the operation was again terminated afterwards without completing the transplant due to the lack of blood pressure in the pig.

***Lesson learnt***
At this level, we felt nephrectomy can be done with confidence and many of the gaps were addressed. Perfusion cannulae needed to be available for faster cooling of the kidney. New sets of vascular surgery instrument and Bookwalter retractor parts needed to be made available. The new problem identified was the suction machine, which was not good enough for vascular surgery. As significant bleeding can occur, adequate suction was deemed a requirement to allow the best opportunity for surgical rescue. The need to do nephrectomy and transplantation in different pigs was apparent.

***Simulation Session IV (Swine #4 and #5)***
***Nephrectomy and Perfusion (swine #4)***
Overall the nephrectomy was very smooth and the kidney was recovered successfully, although the artery was again unacceptably short due to the lack of appropriate stapler. Perfusion was improved by the use of a larger cannula, but was still not ideal.

***Transplant (Swine #5)***
A different pig was anesthetized put in supine position in the adjacent operating theater (recipient OR) and for kidney engraftment (Figure-3). This worked well, as the pig's blood pressure was good throughout the procedure. An extra-peritoneal approach (analogous to that used in humans) was used, which allowed good exposure of the iliac vessels. The problems with instruments and the retractor were addressed. Both venous and arterial anastomoses were completed. The arterial anastomosis was compromised by the lack of an aortic punch. The clamps were released, and the kidney graft was re-perfused successfully (Figure 4). The kidney achieved the appropriate color immediately, the texture and turgidity were appropriate and urine production began immediately.

**Figure 3:** The swine is positioned for transplant in supine position. Note how the legs are fixed and supine position maintained.

Lessons learnt –The collective lessons from all the sessions were summarized and considered. While new challenges were anticipated in humans, the porcine experiences demonstrated possible critical failure points and allowed staff experience with the complex skills and logistics, prior to putting human life at risk.

NB:- After completion of each simulation session, the pigs expired, and bodies discarded according to the veterinary surgeon's protocol.

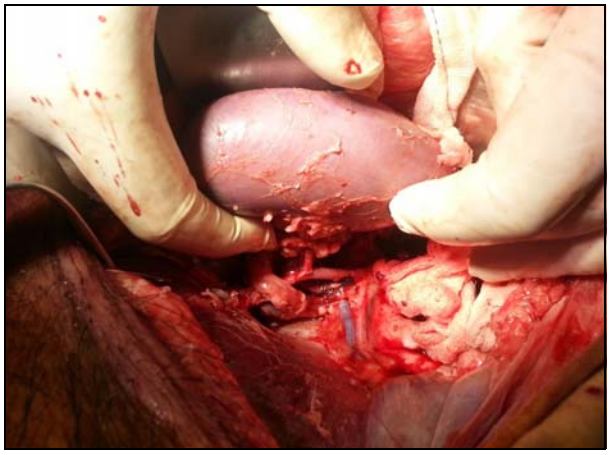

**Figure 4:** At the end of successful swine Kidney Transplant. Kidney color and turgidity looks great. The venous and arterial anastomosis can be seen inferior to the kidney.

***Perceptions of the team members***

Perception interviews were assessed in both in-depth interviews and five scale 10 Liker's item questionnaires. The targets were to interview the four surgeons, five nurses. and three anesthetists. But due to information saturation only three surgeons, three nurses, and two anesthetists were interviewed.

Everyone agreed on the need of doing swine simulation and considered it was worth doing. The surgeons and anesthetists emphasized doing both nephrectomy and transplants are equally important, but the nurses thought the donor nephrectomy simulation was more useful, as laparoscopy was a completely new encounter to them. The nurses felt the process helped them in not only understand the process of donor nephrectomy and transplant, but also identifying and understanding the special surgical instruments used in the surgeries. In addition, they felt that these sessions better prepared them for human surgeries. All of them reported the process increased their confidence in handling humans.

The anesthesia team reported, though the pigs were normal they followed anesthesia protocol for ESRD which gave them a close to normal transplant scenario. It helped them in understanding what donor and transplant fluid management requirements could be, and at which points in the operation communication with surgeons were vital (e.g. diuretics, immunosuppressant, and relaxation).

Though anesthetists were comfortable after the first simulation, all the interviewees agreed in the need to do the simulation until all the team members are comfortable. At each session, they reported different lessons were learnt and issues not seen in the previous sessions were seen. The team felt more comfortable with each simulation as their understanding, coordination and communication improved from one simulation to the other. The nurses and surgeons reported after the fourth session they felt very comfortable, and doing more session was considered unnecessary and they felt they were ready for human surgeries.

The surgeons and the anesthetists (the nurses were indifferent) insisted in doing nephrectomy and transplant in different pigs. This is because keeping the animal in supine and alive with good blood pressure was difficult as seen in the first three sessions.

When asked if a predetermined minimum number of simulation necessary, none of the agreed, rather recommended to continue doing the simulation until everyone is satisfied. All the interviewees

**Table 1:** Mean, Mode and Median Scores of a 5 scale Likert's Item on Perception of individuals involved in Swine simulation

| | | Mean | Mode | Median |
|---|---|---|---|---|
| 1 | Swine simulation helped you understand better what donor nephrectomy details are | 4.6 | 5 | 5 |
| 2 | Swine simulation helped you in understanding what transplant details are | 4.7 | 5 | 5 |
| 3 | Set number of simulations should be done before starting | 3.5 | 5 | 4 |
| 4 | Simulation need to continue until everyone is comfortable and all gaps are identified | 4.3 | 5 | 5 |
| 5 | Swine simulation is not expensive compared to its benefits | 3.2 | 5 | 4 |
| 6 | The swine simulation helped you to work in less stressful situation to understand kidney transplant | 4.3 | 5 | 4 |
| 7 | The swine simulation was close to human transplant in most of it | 4.4 | 4 | 4 |
| 8 | The simulation was interesting and enjoyable exercise | 4.5 | 5 | 5 |
| 9 | Simulation was worth doing | 4.4 | 5 | 5 |
| 10 | I recommend similar simulation in other new centers | 4.9 | 5 | 5 |

## DISCUSSION

It is well established practice to use simulation to teach surgical skills and other interventions for medical students, residents, physicians and surgeons at all level (5,6). This has been done using synthetic materials, animal products, human cadavers, and living animals(5,7). Pigs or its body parts are frequently used for the purpose(8). The aim of surgical simulation is to give trainees a close to real experience under the possible lowest stress, improve patient safety, etc... without putting human life at risk (5). The process can be monitored and progress of trainee can be assessed and feedback given according to performance of the individual (5,7). By using these experiences as a background, the current study added one level or designed a different model to the practice, which is, using swine (animal) simulation to assess if a new center is ready for human care.

Training surgical specialists to perform complex and sophisticated surgical procedures such as laparoscopic donor nephrectomy and kidney transplantation poses a major challenge for any region (3,5). Such endeavors are even tougher in the developing world, due to lack of resource and expertise(1,2). Such high-end training is lengthy, and hands on experience is a must. Simply observing others perform a surgical procedure with the technical complexity of laparoscopic donor nephrectomy or kidney transplantation is insufficient to provide the observer with sufficient skill to perform the procedures independently(3). Even though the objective of the swine simulation was not primarily to teach the transplant fellows how to do donor nephrectomy or transplant, it had a huge contribution in developing their skills as witnessed by the transplant surgeon and fellows in the process.

As the goal of the simulation was to evaluate as many processes of laparoscopic donor nephrectomy and transplantation as possible (for all aspects of the transplant center and all members of the transplant team) prior to initiating the program on human patients, a set number of simulations were not planned from the outset. The number of simulation session needed can vary by specific role and prior complementary experience. After completion of the swine simulation sessions, the team emphasized performance level, rather than the number of sessions, for determination of the need for additional sessions. This is reasonable consideration, as the level of exposure of the team member for the different steps of transplant surgeries were different.

The anesthesia team didn't need much more than one such session for a reasonable understanding of the process. This was because the swine simulation required understanding the special aspect of donors' and recipient's anesthesia, more than actual new skill. After the first session, the anesthesia team understood that they cannot keep the pig alive for a time longer than two hours with good blood pressure that is adequate for doing nephrectomy and transplants on the same pig. It was shown that pigs tolerate supine position poorly (10). When possible and the right instruments and expertise are available, the pig can be intubated through oro-tracheal route, but if that is not the case, as shown in this study, tracheostomy (done by the surgeon) can be used as a safe alternative for airway control (11).

Though it was not a big problem for the anesthesia or nursing team, the surgical team recognized the size of the pig matters a lot right from the first simulation. The difficulty related to the size of the pig was improved with appropriate size, which was between 25-35kgs, and was chosen for the last three sessions. Such size of a pig is not only easier to handle, but also easy to manage the anesthesia and final disposal of the body of the animal (11). Because we didn't have the experience how to do the nephrectomy and the transplant, we were thinking to do both procedures on the same pig in the first three sessions--which didn't work, as the pig cannot tolerate long hours in the supine position (10). Another issue learnt was tissue handling in swine surgery need to be more gentle than typical. Our experience in a few of the sessions was interrupted or required conversion to open due to bleeding resulted from rough tissue handling. This a common reason for conversion of laparoscopy to open in swine and human surgeries (4).

Though doing nephrectomy and transplant on the same animal might save some money, it doesn't closely simulate the actual human surgery and logistics, which was the main goal of the simulation process. A second pig in a second room for the transplant surgery was a better option, as affords the opportunity to also see what logistical needs are required for optimal timing of engraftment. Our experience showed that longer surgeries resulted in low blood pressure for swine, despite adequate fluid administration and minimal bleeding during the surgery, which means we couldn't complete the surgeries. This in turn can reduced our learning opportunities for these sessions.

The perception of the team towards simulation was largely positive. Doing a simulation once or many times was not the factor in testing a new center. Rather, doing the simulation as many times as required in a reasonably short interval (we would say one month) is an important consideration. This could allow for team/institutional memory to develop the lessons learnt. If the time is shorter than that, there will be no enough time to fill the gaps identified, and if it is too long, the experience might fade away. Progress of performance is largely dependent on the pre-simulation paper-based preparations, and level of exposure of the team members to the intended procedure. Debriefing at the end of each simulation, along with adequate note taking and planning together for the next session, as well as guidance by an experienced mentor, cannot be overemphasized.

***Conclusions:*** The experience, knowledge, and skills gained were monumental that we recommend using such a simulation approach to test new complex services in a new center. Simulation sessions should be performed until the team is comfortable and all gaps are identified.

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**Competing Interest:**

The authors declare that this manuscript was approved by all authors in its current form and that no

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