Video Article

Model Surgical Training: Skills Acquisition in Fetoscopic Laser Photocoagulation of Monochorionic Diamniotic Twin Placenta Using Realistic Simulators

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Abstract

Fetoscopic laser coagulation of arterio-venous anastomoses (AVA) in a monochorionic placenta is the standard of care for twin-twin transfusion syndrome (TTTS), but is technically challenging and can lead to significant complications. Acquiring and maintaining the necessary surgical skills require consistent practice, a critical caseload, and time. Training on realistic surgical simulators can potentially shorten this steep learning curve and enables several proceduralists to acquire procedure-specific skills simultaneously. Here we describe realistic simulators designed to allow the user familiarity with the equipment and specific steps required in the surgical treatment of TTTS, including fetoscopic handling, approaches to anterior and posterior placenta, recognition of anastomoses, and efficient coagulation of vessels. We describe the skills that are especially important in conducting placental laser coagulation that the surgeon can practice on the model and apply in a clinical case. These models can be adapted easily depending on the availability of materials and require standard fetoscopy equipment. Such training systems are complementary to traditional surgical apprenticeships and can be useful aids for fetal medicine units that provide this clinical service.

Video Link

The video component of this article can be found at https://www.jove.com/video/57328/

Introduction

The acquisition of a new, minimally-invasive surgical technique often employs the traditional surgical apprenticeship model in which an individual learns from observing an expert surgeon operate on a live patient and eventually performs the technique under close supervision[1]. This time-honored model often limits the passage of knowledge from mentor to individual trainee and relies heavily on the availability of resources such as training funds and patient case-load[2]. Fetoscopic surgery is an example of a high-risk minimally-invasive surgery, performed on a preterm individual during pregnancy in which there are risks to both the mother and fetus. As with any surgical procedure, higher complication rates arise at the initial steep slope of the learning curve. Thus, surgeries are usually performed by the most senior or skilled surgeon in order to meet the critical volume of cases to optimize patient outcomes[3].

Good fetoscopy skills are important for the future of fetal therapy, which strives to be minimally invasive, even with respect to the correction of structural defects[4,5,6]. Fetoscopic surgery is technically challenging and there are inherent risks to patient safety associated with practicing and developing new skills in the real-life theater environment. Even established surgeons require time and consistent practice on multiple patients to acquire expertise, skills in troubleshooting when difficulties arise, and the instinct to predict and avoid pitfalls in a new and complex procedure. There is less tolerance for suboptimal outcomes usually associated with novice proceduralists[7]. While it is important not to compromise patient safety during the initial implementation of fetoscopic surgery, there is also a need to enhance the efficiency with which skills and expertise are acquired by all proceduralists, particularly in smaller clinical units just beginning to practice fetoscopy. An alternative system complementary to traditional apprenticeship is needed to meet the challenges of limited training funds and a small patient base on which to master these highly specialized procedures. Procedural learning curves can be shortened, and complications reduced by training on high-fidelity machines or cadaveric animal models, with dedicated traditional mentoring or distant proctorship and procedure-focused stepwise learning[8,9,10,11]. Familiarization with the fetoscope manipulation, intrauterine orientation of the vascular equator, and laser coagulation before performing the actual surgery has the potential to reduce operative complications[12,13]. This training may shorten the learning curve for new operators as they master basic skills on a realistic tissue model.

Monozygotic twinning occurs with uniform frequency worldwide affecting 3-5 per 1,000 pregnancies, and the 75% of monozygotic twins with monochorionic diamniotic (MCDA) placentation are at significant risk for TTTS, which currently complicates about 10-15% of MCDA pregnancies, or 1-3 per 10,000 births[14]. The incidence is expected to increase with the frequency of in vitro fertilization (IVF) in which there is a 2 to 12-fold increase in monozygosity[15,16,17,18,19]. TTTS arises from unidirectional inter-fetal blood flow via deep intraplacental AVA. Untreated, this carries a 60-100% mortality and significant morbidity for surviving fetuses[20,21,22].

Selective fetoscopic laser coagulation (SFLP) is the only curative intervention aimed at the rescue of both twins via fetoscopic identification and ablation of the offending AVA, and is considered the standard of care in TTTS stages II-IV (~ 93% of all cases) in pregnancies at < 26 weeks of gestation, with clinical studies in progress to determine if it should also be applied to selected stage I disease[23,24,25]. SFLP carries an overall perinatal survival of ~ 70% with a higher likelihood of more advanced gestation and higher birth weights at delivery[26,27] and is considered superior to other interventions as it directly rectifies the underlying pathology of TTTS[28,29,30]. The intervention itself is not without complications, and laser-treated TTTS is associated with recurrence (0-16%), perinatal mortality (~ 35%), and a 5-20% chance of long-term neurologic handicap[23]. Acquisition of the correct skills, building expertise over a steep learning curve, adherence to international standards of fetoscopic practice, and maintaining surgical dexterity are essential to providing the best outcomes in this complex disease[13,31,32,33]. This is often dependent on financial and human resources and a critical volume of cases that may take significant time to acquire[34]. Established fetal therapy centers are currently concentrated in Western Europe and North America, but the predicted population boom (and thus new pregnancies) will mostly affect Asia and Africa[35,36]. Therefore, an increase in the incidence of fetal anomalies amenable to intrauterine treatment can be expected in these lower-resource populations. The dissemination of specialized services such as fetoscopic surgery is a challenge that needs to be addressed as a regional priority[37]. New fetal therapy centers in these regions must reliably provide SFLP services to meet the needs of their communities, but significant investment and time is needed for new centers to achieve equivalent outcomes as established ones[38,39,40,41].

Departing from the resource-heavy apprenticeship model will facilitate a much-needed dissemination of skills and expertise to communities in which there is a great demand for it. The traditional surgical apprenticeship is still relevant but less practical for many smaller clinical units, as it is time- and resource-consuming and limits the passage of knowledge and skills to one trainee at a time. Simulator training under proctorship is more applicable on a wider scale and facilitates the passage of knowledge and skills passed from one expert to multiple persons through workshops and regular skills training on reliable tissue models[13,42,43]. It has been suggested that, because of its rarity, TTTS treatment should be accumulated in high-volume fetal centers to improve its outcomes. Yet, there is also a need to establish new fetal care centers to improve patient access to treatment. Emerging fetal care centers, like the National University Hospital in Singapore (NUH), will need to adhere to certain guidelines in order to maintain their surgical outcomes, *i.e.*, Siriraj-NUH proctorship system as seen in **Figure 1**[37].

In this article we will describe a model-based system with which new proceduralists can undergo skills training in tandem under the guidance of an expert proctor, and by which skills can be practiced to maintain surgical dexterity during long intervals between patients. We will share practical points from our experiences at the Siriraj Hospital in Bangkok and the NUH in Singapore in initiating fetal therapy[6,44,45].

Protocol

The collection of human placenta from term deliveries was approved by the Domain Specific Review Board of the NUH of Singapore (DSRB C/00/524) and by the Siriraj Institutional Review Board (SIRB 704/2559) of Siriraj Hospital in Bangkok. In all cases, patients gave separate informed written consent for the use of the collected specimen. The pig bladders were collected from a local butcher in Singapore and were a kind donation from Dr. Ying Woo Ng (NUH). The non-human primate (NHP) placentas were waste material collected from breeding *Macaca fascicularis* under the Ministry of Health (Singapore) National Medical Research Council grant NMRC/CSA/043/2012, strictly adhering to the Institutional Animal Care and Use Committee (IACUC) at the National University of Singapore and Singapore Health Services Pte Ltd (IACUC 2009-SHS-512) and were a kind donation from A/Prof Jerry Chan.

1. Familiarization with Fetoscope Handling and Placental Orientation Using a Fetoscopy Simulator

1. Set up the fetoscopy simulator and equipment (**Figure 2A - C**).
    1. Identify the parts of the 2.0 mm fiber straight fetoscope: the lens (0° or 30°), standard or remote eye-cap (**Figure 2A**); the 3.0 mm double lumen operating sheath with sharp obturator tip for direct insertion into amniotic cavity under ultrasound guidance, for use with the 2.0 mm fetoscope (**Figure 2B**).
    2. Place the fetoscope into the operating sheath after removal of the obturator and connect the eye-cap to the laparoscope camera.
    NOTE: These straight fiber-endoscopes are semi-flexible and operating sheaths can be carefully bent up to 20-35° from the midline axis to provide the appropriate curvature for use with anterior placentas. Bend the operating sheath without the endoscope inside. Other suitable fetoscopes for posterior and anterior placentas are listed in the **Table of Materials**.

2. Arrange the laparoscope tower and ultrasound machine near the "operator" so that the ultrasound probe can be manipulated at the same time during the fetoscope insertion.
    1. Fill the fetoscopy simulator to the brim with water through one of the one-way valve ports.
    2. Position the filled simulator on the plastic base in the desired orientation to represent either an anterior or posterior placenta (**Figure 2C**).
    NOTE: The upper surface of the simulator will now represent the anterior maternal abdomen where the ultrasound probe is placed and where the fetoscope should be inserted.

3. Use the curvilinear ultrasound probe with aqueous gel on the transparent skin of the "anterior maternal abdomen" to visualize the placenta within the fetoscopy simulator. Identify the placental location and a window adjacent to it (for an anterior placenta) in which to place the fetoscope.

4. Insert the appropriate fetoscope in the operating sheath through the port under continuous ultrasound guidance (**Figure 2C**).
    1. Use the 0° straight fetoscope for a posterior placenta and the 0° curved fetoscope for an anterior placenta (**Table of Materials**).

2. Monitor the insertion and depth of the fetoscope by ultrasound and bring the placenta into view.
3. Adjust the focus of the camera to bring the vision into sharp relief (**Figure 2D - F**).

5. Identify the inter-twin membranes which are juxtaposed to the vascular equator.
   1. Identify the vascular equator on the surface of placenta and explore the vasculature moving from end-to-end systematically to identify the typical AVAs for ablation.
   NOTE: These anastomoses will be seen running on the chorionic surface; the artery is darker and always runs over the vein (**Figure 2C,E**).

6. Change the orientation of the simulator to represent the posterior placenta if practice has been done with an anterior placenta, or vice versa.
   1. Repeat the process of ultrasound assessment, planning fetoscope entry, and inserting the fetoscope.
   Note: The orientation of the simulator and thus of the placenta can be changed each time to practice the fetoscopic placement for various positions of placenta, and also to test out different (curved, straight) fetoscopes.

2. Tissue Models for Practice of Direct Fetoscopic Entry, the Seldinger Technique, and Laser Coagulation of Vessels

1. Tissue model #1 - Placenta in a box
   1. Create the box model using a standard, store-bought plastic container of 35 x 18 x 15 cm^3 dimensions with a watertight lock (**Figure 3A**).
      1. Cut out a wide window of the plastic cover and replace it with ultrasound-transparent rubber "skin" stitched to the margins of the cover. This forms the anterior surface of the simulated maternal abdomen through which the fetoscope is placed. Mount a rubber latex sheet along the bottom of the box to prevent sonographic reverberation (**Figure 3A - C**).
   2. Collect human placentas after term births, with the proper consent for sample collection. Wash the surface of the placenta with tap water in the sink (it is best to do so in the utility room of the labor ward before transport). Ensure that the placental surface is clean of blood and cut the umbilical cord using strong tissue scissors to a manageable length, *e.g.*, 5 cm.
      1. Transport the placenta in a sealed biohazard plastic bag within a secondary container to the laboratory.
      NOTE: Always handle the placenta and other biological substances using personal protective equipment (disposable gloves, eye shields, *etc.*). Ensure the proper institutional ethical approvals are in place before carrying out this work.
      2. Tie the free end of the umbilical cord by a suture band or cotton cord tape to prevent the blood running out of the cut end.
      NOTE: The blood in the vessels will also help simulate vessel laceration from over-coagulation during laser practice.
   3. To simulate an anterior placenta, fix the placenta to the re-fashioned lid of the container with clear plastic thread or a plastic net to hold it in place.
   4. To simulate a posterior placenta, fix the placenta to the rubber sheet at the bottom of the container and hold it in place with a plastic net or small weights (**Figure 3B**).
   5. Fill the container with tap water and lock the lid in place.
   6. Prepare the 0° straight fetoscope for a posterior placenta and its operating sheath with working channel, and the multichannel 0° curved fetoscope for anterior placenta (**Table of Materials**). Connect the eye-cap to the camera.
      1. Prepare the laser. For example, if using the diode laser with a 400-μm or 600-μm laser fiber, set the initial voltage at 15-30 W and gradually increase if needed for effective coagulation.
   7. Perform the ultrasound assessment of the placenta as described in step 1.3.
      1. Find a placenta-free window adjacent to the anterior placenta in which to insert the curved fetoscope such that the lens lies above the center of the placenta (where the inter-twin equator is expected to be in a MCDA placenta).
      2. Determine where to insert the straight fetoscope for the posterior placenta such that the 0° lens is positioned perpendicular to the center of the placenta.
   8. Perform direct fetoscopic entry by making a 2-mm stab incision with a sharp blade in the "skin". Insert the operating trocar with its pyramidal obturator into the fluid-filled container (the "amniotic sac") under continuous ultrasound guidance (this is the sac of the recipient twin in a patient).
      1. Avoid piercing the placenta by advancing the fetoscope slowly under ultrasound vision. Remove the pyramidal obturator from the operating trocar slowly under continuous ultrasound vision.
      2. Place the lens of the fetoscope carefully into the operating trocar in the channel previously occupied by the obturator, and bring the placenta and surface vasculature into sharp focus (**Figure 3C**).
   9. Insert the laser fiber into the operating side-channel and advance slowly as the tip nears the end of the sheath.
      NOTE: Keep the laser beam as perpendicular as possible to the target vessel in order to maximize the laser effect[46,47].
      1. Advance the laser fiber tip to approximately 5-10 mm beyond the operating sheath.
      NOTE: If the laser tip advances too far from the sheath, it may lacerate the vessel. If the tip is too close, the coagulation effect may be compromised (**Figure 3D**). The laser fiber tip should be 2-3 mm from the vessel surface and should not touch the vessel when fired (yellow arrow in **Figure 3D**).
   10. Identify the umbilical cord (**Figure 3E**) and placental vessels (**Figure 3F**). Review the placental vasculature end-to-end using a combination of ultrasound and direct fetoscopic vision.
       NOTE: The fetoscope should be directed at a 90° angle to the target vessel. **Figure 3G** shows the actual monochorionic AVA in a monochorionic placenta. Use the foot pedal to fire the laser when in position perpendicular to the vessel or anastomosis.

11. Coagulate the vessel until it blanches with the no-touch technique and aim to coagulate a segment of 1-2 cm until complete cessation of flow is accomplished. The vessel should appear flattened (collapsed) and pale for coagulation to be deemed effective.
    1. Systematically practice coagulation of vessels from one placental end to the other. Laser coagulate the thick vessels from the periphery towards the center of the vessel to prevent rupture (thus "shaving" a thicker turgid vessel into a narrower less congested one). Alternatively, coagulate the smaller feeding vessels first before the larger ones to allow decongestion and prevent vascular rupture.

12. Practice the Solomon technique after individual vessels have been coagulated to complete placental dichorionisation[48,49]. Create a line on the placental surface by superficial coagulation with the laser until all the individually-coagulated anastomoses are joined.

2. Tissue model #2 - Pig bladder "uterus"
   NOTE: A hybrid tissue model combining a pig bladder and a mid-trimester human placenta may also be considered for simulation if the materials are readily available. This model can be used to practice insufflation and removal of fluid from the "uterus" to recreate commonly encountered complications of fetoscopy like blood-stained liquor, and to practice the Seldinger technique of fetoscope insertion.
    1. Acquire a cleaned pig bladder. Position it with the broader curved perimeter as the upper cephalad pole and the narrower portion as the lower caudal pole, so that the user can bisect along the cephalad border and proceed caudally, such that the bladder opens like a clamshell (**Figure 4A**, broken line).
       NOTE: Perform all procedures with human and animal tissues in a biological safety cabinet wearing personal protective equipment and with the appropriate institutional approval for handling biological tissues.
    2. Acquire a small mid-gestation human placenta after delivery or medically-induced pregnancy termination. Ensure that the proper consent is attained, and the specimen is anonymized.
    3. Trim the excess amniotic membranes from the placenta (filmy, white tissue attached to the fetal/umbilical surface) using tissue scissors and suture the placenta (red arrow, fetal surface outwards, maternal surface inwards) around its perimeter to one half of the pig bladder. Suture the second half of the pig bladder (black arrow) to the first around the incision in a water-tight fashion (**Figure 4B, C**).
    4. Place the "uterus" in the model pelvis as shown in **Figure 4D**. Orientate the uterus to simulate either an anterior or posterior placenta (**Figure 4D**).
    5. Under ultrasound guidance (if the rubber skin is transparent to ultrasound) practice direct insertion of the trocar and fetoscope within its operating sheath.
    6. Practice the Seldinger technique using a sharp hollow trocar inserted into the amniotic space under real-time ultrasound guidance. Advance the soft J-tipped guidewire through the lumen and withdraw the trocar, passing a blunt cannula loaded with a dilator over the guidewire into the amniotic space before withdrawing the guidewire and dilator altogether, leaving the cannula in place. Finally, insert the fetoscope into the uterus via the cannula (**Figure 4E**).
    7. Examine the vessels on the placental surface fetoscopically. Reduce or add fluid via the operating channel with a 50-mL syringe to increase or decrease "intrauterine" pressure and to replace blood-stained or turbid fluid with fresh saline.
    8. Practice laser coagulation of vessels in the same manner described in steps 2.1.11-2.1.12.
    9. Dispose the model as biohazardous material according to institutional protocol.

# 3. Transferring Skills Learned on the Model to the Human Patient

1. On the patient with a MCDA twin pregnancy, perform ultrasound examination of the placenta and identify the cord insertion points of both fetuses on the placenta.
   NOTE: In this case, one of the cords may be inserted close to the margin of the MCDA placenta. Imagine a line joining the two placental cord insertions and determine the midpoint of this line which indicates the location of the vascular equator and may be closer to the smaller donor twin rather than equidistant to both cords especially with a significant amniotic sac size discrepancy. The vascular equator lies perpendicular to the line joining the cords.
2. Determine the site of fetoscope insertion.
    1. For an anterior placenta, find a window under ultrasound visualization of the placenta, free from placental tissue, from which the curved fetoscope can be manipulated such that the lens lies over the vascular equator.
    2. For a posterior placenta, insert the fetoscope at the approximate midpoint between the cords directly over the vascular equator. Move the fetoscopic lens up and down the vascular equator using a sweeping movement while maintaining an approximately 90° angle to the equator, optimal for laser coagulation.
   NOTE: This may require the insertion site to be lateral to the vascular equator, just beyond the periphery of the placenta on the side of the polyhydramnios sac.
3. Check for completion of placental dichorionization after the delivery of the fetuses to assess for residual anastomoses (**Figure 5A - C**). Inject the umbilical cord vessels with different colored dyes to distinguish between the donor and recipient arteries and veins after the necessary preparation as previously described[44,50].

Representative Results

The basic requirements for a fetoscopy simulator are a transparent "skin" that enables ultrasound visualization of the placenta within the model and a representative model of the MCDA placenta. The simulator illustrated here was developed at Siriraj Hospital (Bangkok), and is a closed system that incorporates a silicon replica of a mid-gestation monochorionic placenta (**Figure 1**). The consistent use of this model should increase the confidence of the novice surgeon in placental orientation and fetoscope placement and increase familiarity with handling of the straight and curved fetoscopes. Practice on the tissue models will increase the surgeon's familiarity with laser coagulation of placental vessels and troubleshooting common pitfalls such as rapid vascular bleeding and ruptured vessels. The singleton placenta is a good substitution for the monochorionic placenta if the latter is unavailable. The model should be assembled with easily available equipment and term placenta (**Figure 2**, **Figure 3**). The surgeon should be confident in examining vessels along the full length of the placenta and their systematic laser coagulation with the consistent use of either tissue model. If vascular coagulation is performed completely this will be evident through the absence of deep anastomoses; dichorionization is completed with the Solomon technique ablating the superficial anastomoses along the equator (**Figure 4**). Once the surgeon is confident in the skills honed on the models, the transition to the human patient is smoother. The examination of the placenta and residual anastomoses is an important step in gauging the efficacy of the surgery; consistent feedback to the surgical team on the efficiency of treatment aids them in recognizing technical flaws and improving their surgical outcomes in future cases.
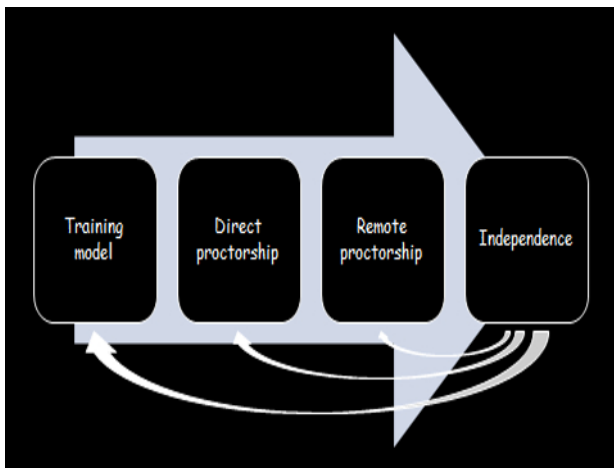

**Figure 1: Workflow in a new fetoscopy unit.** Please click here to view a larger version of this figure.
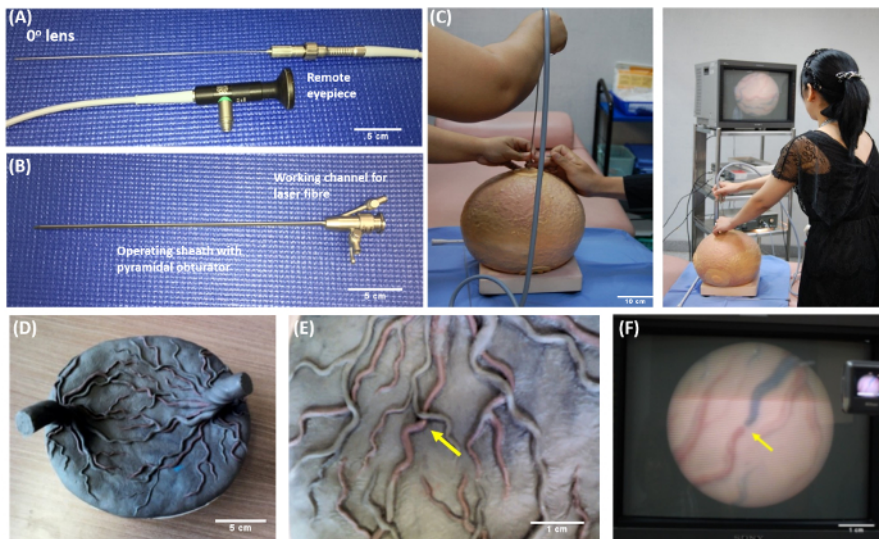
Figure 2: Fetoscopy simulator. Parts of the fetoscope include (**A**) the straight telescope with 0°lens, remote eye-cap for attachment to the laparoscopy camera, and (**B**) operating sheath with side channels for laser fiber introduction and infusion/aspiration of fluid. This simulator can be orientated to practice the approach to an anterior and posterior placenta (**C**). The simulator incorporates a silicon replica of a mid-gestation monochorionic placenta (**D**), and presents to the operator a series of arterio-venous anastomoses (**E**, **F** arrow) among other placental vessels to recognize. Please click here to view a larger version of this figure.
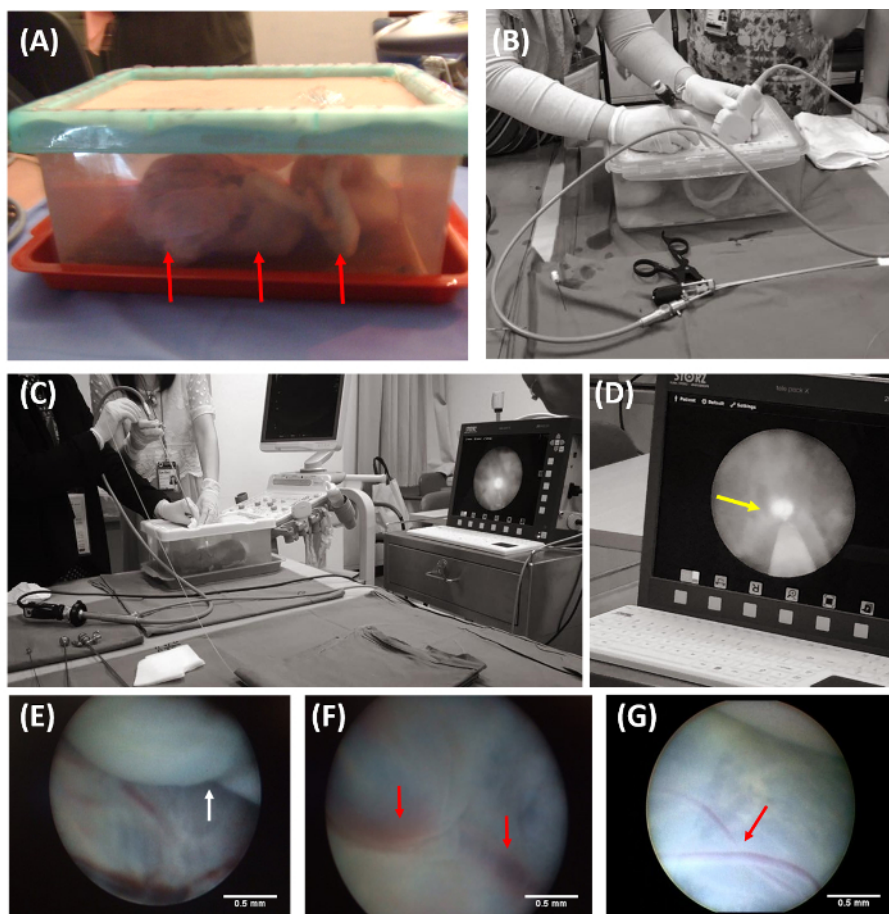
Figure 3. Tissue model #1. This model is easy to assemble and requires rubber "skin" fitted over an opening cut out of the lid, which is transparent to ultrasound (**A**). The placenta (red arrows) is placed at the base of the container and held down by weights to simulate a posterior placenta. The operator can practice ultrasound assessment of the entry site and fetoscope insertion simultaneously to improve dexterity (**B**, **C**). Laser photocoagulation of vessels can be practiced (**D**, yellow arrow showing laser fiber tip and laser point). Visualization of the umbilical cord (**E**, white arrow) and vessels (**F**, red arrows) in this singleton placenta allows for realistic simulation of the actual monochorionic AVA (**G**, red arrow) for laser practice. Please click here to view a larger version of this figure.
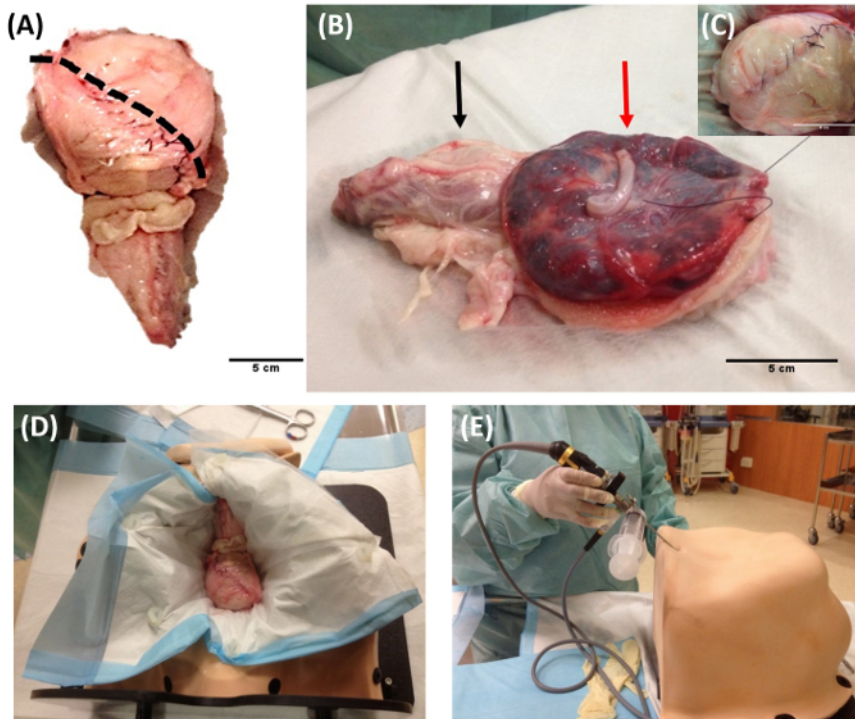
Figure 4. Tissue model #2. This model was created by bisecting a pig bladder (along the black broken line, **A**) and suturing a *Macaca fascicularis* placenta (red arrow) into the interior and closing it in a watertight fashion (**B**, black arrow, and **C**). The bladder "uterus" was reconstructed using two layers of sutures and injected with fluid before placing it into a model pelvis (**D**). If the model pelvis is covered with ultrasound-transparent "skin", the operator can practice ultrasound-guided direct and Seldinger methods of fetoscopic entry (**E**), and also increase and decrease intra-amniotic pressure to improve visualization. Please click here to view a larger version of this figure.
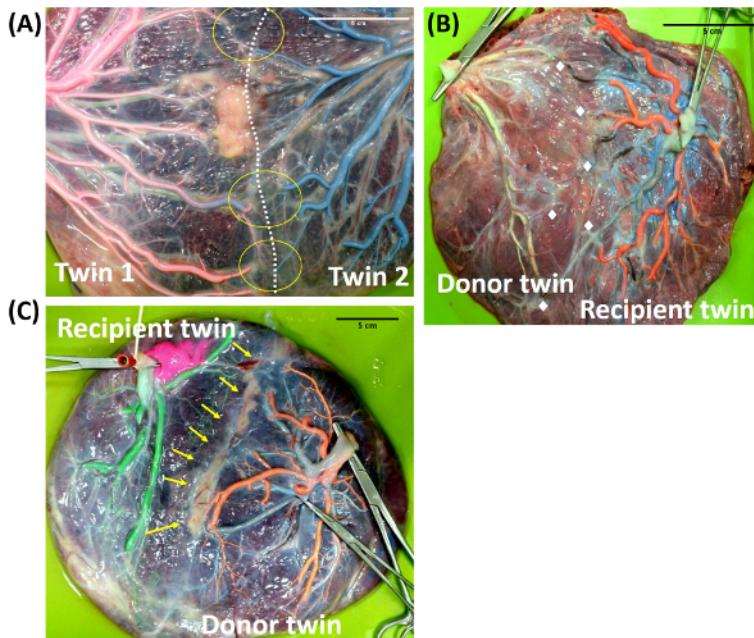
Figure 5. Placental injection studies. These dye injections were performed on MCDA placenta after delivery. (**A**) Untreated MCDA twins without TTTS indicating AVA (circles) and vascular equator (dotted line). Treated MCDA placenta with coagulated AVA (**B**) and dichorionization by Solomon technique (**C**, yellow arrows) indicating efficiency and completeness of treatment. Please click here to view a larger version of this figure.

Discussion

The skills practiced on a fetoscopy simulator and on the tissue models encompass the majority of technical abilities required for SFLP. The advantages of training on these models include learning to simultaneously handle the ultrasound probe and fetoscope, familiarity with handling

the straight and curved fetoscopes, practicing the systematic examination of the vascular equator along the whole length of the inter-twin membrane to identify anastomosing vessels on high-fidelity MCDA placenta, and learning the correct techniques to use on large and high-flow vessels to avoid rupture, which may lead to serious consequences including sudden loss of vision and exsanguination of one or both twins. Additional practice can be done to simulate the superficial laser ablation used in the Solomon technique. Acquired skills are directly applicable to procedures performed on the pregnant patient. Regular practice will train the surgeon towards the goal of safely ablating all visible AVAs on the vascular equator of the MCDA placenta while minimizing the risk of twin anemia polycythemia sequence (TAPS) after SFLP[51].

The team at Faculty of Medicine Siriraj Hospital has developed a proprietary phantom to enhance the learning experience of the surgeon. This 35 cm diameter soft rubber spherical model simulates the intrauterine environment for skills acquisition and improvement[45]. It contains a rubber replica of a monochorionic placenta and one-way valve ports to allow orientation of fetoscopes to an anterior and posterior placenta. Water can be infused through these ports and the proprietary covering material is transparent to ultrasound. This closed-system model allows the systematic examination of placental vessels, particularly the AVA responsible for TTTS, and fluid can be infused and removed to simulate the clearing of bloody or cloudy amniotic fluid. The operator can also practice the simultaneous handling of the ultrasound and fetoscope as is required during surgery.

The tissue models can be modified and adapted according to the available resources of any fetal therapy unit. A pig bladder can be purchased from the local butcher to be used as the "uterus", while placenta from preterm deliveries or mid-trimester pregnancy terminations can be used in the box or bladder model to better simulate the mid-trimester MCDA placenta for fetoscope insertion and coagulation practice. We used NHP placentas of equivalent size that were waste material following ethically-approved NHP breeding (see the ethics statement). These models are generally easy to assemble using available materials and do not require live animals, which have also been used for fetoscopy training[52,53,54]. The MFM team functioning within a maternity unit should have placentas of various gestations available for use with the appropriate ethical approvals and consent processes in place.

With these realistic tissue models, the operator is able to practice the two, main ultrasound-guided fetoscopic entry techniques and laser coagulation of vessels in a practical setting. The operator can rehearse practical troubleshooting steps that are often needed in the course of surgery, such as cutting off the spent laser tip to refresh the fiber to enable sharp focus of the laser, controlling the bleeding from a ruptured vessel, adjusting the amount of laser fiber extending from the operating sheath for efficient coagulation, and clearing turbid "amniotic fluid" to improve vision. This system can incorporate comprehensive assessment tools such as the Delphi method to assess competence prior to independent performance[12]. Both anterior and posterior orientations of the placenta can be approached using the curved or straight fetoscopes, respectively and the operator gains mastery of both instruments. These models can be produced in volume quickly for workshops to allow new and seasoned proceduralists to train at the same time. Additionally, the surgical team (main surgeon and assistants) can practice the various steps together to enhance efficiency. The main risks are biological: the animal and human tissues should be treated as biohazardous material. Protocols should be in place to acquire placenta only from postpartum patients who are free of transmissible infectious diseases. Sharp instruments used for suturing and cutting should be handled with the appropriate caution and disposed of properly to avoid sharps injuries. The operator will be working with singleton placenta most of the time, and thus will not have the opportunity to screen for AVA.

Training on realistic simulators may allow a team of proceduralists to master skills simultaneously, thus facilitating the rapid initiation of services at a new fetal therapy center. Skills practiced on the simulator and tissue models are directly applicable to the human patient, further lowering the learning curve for new proceduralists, who should be mentored by an experienced fetoscopist in the initial training phase focused on mastering the specific steps of fetoscopy while minimizing complications. Surgeons can practice their skills with these models on a regular basis to maintain surgical dexterity, particularly during long intervals between patients.

Disclosures

The authors have nothing to disclose.

Acknowledgements

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