Video Article

Porcine As a Training Module for Head and Neck Microvascular Reconstruction

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Abstract

Live models that resemble surgical conditions of humans are needed for training free-flap harvesting and anastomosis. Animal models for training purposes have been available for years in many surgical fields. We used the female (because they are easy to handle for the procedure) Yorkshire pigs for the head and neck reconstruction by harvesting the deep inferior epigastric artery perforator or the superior epigastric artery perforator flap. The anastomosis site (neck skin defect or tracheal wall defect) was prepared via the dissection of the common carotid artery and the internal jugular vein, in which 3.5× loupe magnification was used for anastomosis as we use on human cases in real life. This procedure demonstrates a new training method using a reliable learning model and provides a detailed anatomy in a live scenario. We focused on the ischemia time, harvesting, vessel anastomosis, and designing the flap to fit the defect site. This model improves tissue handling and with the use of proper instruments can be repeated many times so that the surgeon is fully confident before starting the surgery on humans.

Video Link

The video component of this article can be found at https://www.jove.com/video/58104/

Introduction

Reconstruction following surgery for the head and neck malignant diseases is a difficult procedure associated with significant morbidity. Microvascular free-flap reconstruction has been well established as the standard approach to reconstruction for over 20 years[1,2,3]. Free-flap transfer plays a significant role in improving the head and neck management in cancer patients and in post-traumatic injuries thereby pushing the boundaries of surgical excision of disease beyond previous techniques, resulting in greater patient quality of life and longer survival rates[1,2,3]. The various flaps for reconstruction include rotational, graft, and free flaps.

The role of free flaps in the head and neck reconstruction has expanded. It is the most difficult flap to work with, requiring skilled and delicate handling. Flap failure is a catastrophic event, with significant morbidity[4,5]. Thus, considerable training time is required to develop the precision necessary for the successful surgical outcomes[3,4,5,6,7,8,9]. The steep learning curve associated with such a surgery can influence the outcome for patients and affect treatment management[3,4,5,6,7,8,9]. To reduce the training time and learning curve for new surgeons, a training model is needed that mimics human biology and provides similar surgical field conditions[8].

The goal of this study is to show the visibility of Porcine as a good training module for the head and neck microvascular reconstruction resembling the human case with improved skills in the active fashion.

This study investigated the use of a porcine model for training new colleagues in the head and neck microvascular reconstruction for free-flap transfer to provide a cost-effective and less stressful supplement to the clinical field training with reliably similar features for free-flap procedures. Pigs have been used for many studies and as teaching models for various surgical reconstructions, *e.g.,* breast reconstruction;[5] however, pigs have never been used for head and neck reconstruction except in our study for tracheal reconstruction due to tracheal stenosis[10].

The idea was started after Frederic Bodin[7], who describe the similar flap for breast reconstruction. The main advantage for the study over the other module of microvascular training is the active livening module with a real immediate result of the procedure.

Protocol

This study was guided and approved by the Department of Laboratory Animal Resources, Yonsei Biomedical Research Institute, Yonsei University College of Medicine, accredited by the Association for Assessment and Accreditation of Laboratory Animal Care International. This study followed the guidelines for the Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources Commission on Life Sciences National Research Council. All Pigs were acclimated for One week before the operation.

1. Preparation

1. Keep the pigs without food for over 12 h before general anesthesia with free access to water.
   Note: Six female Yorkshire pigs were used weighing 25–30 kg each.
2. Use a 16 Gauge Needle of 1 cm length to intramuscularly inject alfaxan (1 mg/kg), xylazine (2 mg/kg), and azaperone (2 mg/kg) behind and below the ear to initiate anesthesia.
3. Shave the anterior midline of the neck and the abdominal wall of the pig using a surgical hair removal shaver.
4. Secure an intravenous (IV) route through central or marginal ear vein on the posterior side of the auricle with a 22-G needle. Inject Ketorolac (1 mg/kg) via an IV line.
5. Then inject atropine (0.04 mg/kg) intramuscularly as described in 1.2. Inject cefazolin (30 mg/kg) intramuscularly as described in 1.2.
6. Put the pig lying down in a supine position over the Operating room table.
7. Allow the pig to breath 2 L of oxygen with 5% of isoflurane through Swine anesthesia mask spontaneously.
8. Expose the vocal cords through the mouth by using a laryngoscope and spray them with two puffs of 2% Lidocaine topical solution to prevent intubation-induced laryngospasm.
9. Intubate with a 6.5 mm tube, inflate the tube cuff with 3-5 mL of air using a syringe without a needle attached to it.
   Note: Perform capnometry to ensure that the tracheal tube, which is a part of the anesthesia machine, is in proper position and there is CO_2 back to the machine as an indication of proper oxygenation.
10. Maintain the anesthesia after the intubation with 2% isoflurane.
11. Use the vet ointment on pig's eyes and close it with an eye cover patch.

2. Procedure: Reception Site

1. Disinfect the neck and the abdominal wall with the iodine-based scrub solution 1%.
2. Start a vertical midline incision in the anterior neck using blade No. 23 up to the sternum.
3. Dissect the strap muscles and retract it laterally using Kelly tissue scissor and Lahey retractor.
4. Expose the trachea from the first ring to the thoracic inlet.
5. Then, expose the common carotid artery and the internal jugular vein for the anastomosis.
6. Create a window in the second or third tracheal cartilage, ~1 cm in width using blade no. 11.
7. Look for the endotracheal tube through the tracheal defect created, and make sure the aeration through the tube is continued using the ventilator without a leak.

3. Procedure: Flap Site

Note: The superior epigastric artery perforator (SEAP) flap harvest can be performed, according to the method described by Frederic Bodin[7].

1. Design a flap on the upper abdomen by a surgical marker pen (**Figure 1A**).
2. Create an elliptical Skin incision 4 x 3 cm using a No. 23 scalpel to the anterior sheath of the abdominal wall on the medial side of the drawn flap (**Figure 1B**).
3. Elevate (peel) the Flap from the *rectus abdominis* muscle sheath looking for the perforators going to the skin flap while holding the fascia by the allis.
4. Perform the intramuscular dissection and follow the perforators to the superior epigastric vessels (**Figure 1B**)
5. Now perform the lateral skin incision on the designed flap (**Figure 1A**) using a No. 23 scalpel (**Figure 1C**)
6. Clamp the superior epigastric vessels and *venae comitantes* with the hemostat superiorly and use Kelly tissue scissors to cut below the hemostat and ligate the vessel above the hemostat by 3-0 suture. Then take off the hemostat.

4. Anastomosis and Closure

1. Put on a surgical loupe.
2. Clamp the Carotid artery using two hemostats with 1-2 cm distance between them.
3. Use micro-scissors to cut between the carotid artery and tie the superior part by double suture insure no oozing.
4. Use the double clamp without the frame between the carotid artery and flap artery.
5. Start anastomosis by using 10-0 suture simple full thickness interpreted.
6. Place the first two stay sutures approximately 120 degrees apart on the vessel's circumference then in between place 2-3 stitches.
7. Release the clamp. If there is blood oozing do the similar suture at the oozing site.
8. Look for the venous back flow from *venae comitantes*.
9. Perform anastomosis as described in step 4.1 to 4.7 for the internal jugular vein and *venae comitantes* (**Figure 1D**).
10. Use a syringe needle size 18 to prick the skin to ensure flap viability by seeing a blood drop.
11. Close the tracheal window and suture it with the *muscle fascia* of the SEAP flap using 3-0 suture.
12. Exteriorize and suture a skin paddle of the SEAP flap to the cervical midline skin incision (**Figure 2A**).

13. Close the abdominal skin incision (**Figure 2B**).

5. Post-operative Care

1. Get the pig back into the prone position.
2. Stop the isoflurane and wean the pig from the ventilator.
3. Allow the pig to recover in the animal cage and monitor it closely to ensure its smooth recovery from the procedure.
4. Look for the flap at reconstruction site after healing (**Figure 2C**).
5. Look at the donor site in the animal after healing (**Figure 2D**).
6. Start Ringer's lactate at the rate of 150 mL/h until full recovery and administer 0.3 mg buprenorphine for analgesia.
7. Following extubation, monitor the pig closely until it has regained sufficient consciousness to maintain position and breathing and is able to drink spontaneously.
8. Keep the post-surgery pigs in separated place from no operated animals.
9. Start intramuscular amoxicillin–clavulanate (14 mg/kg) for 1 week.
10. Start intramuscular Meloxicam (0.2 mg/kg) for 1 week.

6. Euthanasia

1. Start anesthesia for the pig by injecting propofol through i.v. (5-10 mL) and maintain it with isoflurane 5%.
2. Intubate the pig as described on step (1.1, 1.2, 1.6-1.10).
3. Induce the cardiac arrest by intravenous injection of 40 mmol KCl.

Representative Results

We performed the procedure on six pigs: cervical skin defect reconstruction on two pigs, tracheal reconstruction on two pigs, and free flap to test vascular anastomosis device in two pigs. The pigs were monitored for 3 months and there was no clinical sign of neurological deficit.

The mean time for ischemia was 50 min (range, 35-80 min); the time decreased as the procedure was repeated. The mean harvest time of the six pigs was 55 min. There is no morbidity happen at the donor site in our module. The mean pedicle size of the flaps was 10 cm, which is similar to most that in the human head and neck. The mean artery diameter was 4.5 mm quite larger than human 2 mm, and the mean vein diameter was 5.84 mm also quite larger than human 2 mm although it simulates the real-life experience. The Skin paddle size ranging from 25 cm^2 to 40 cm^2 without significant effect in Flap failure (**Table 1**).

With practice, repeated confidence, skill and time of surgery was improved. Unfortunately, the case number 5 was getting longer time in harvesting and anastomosis. The flap in this case end with the total loss plus the diameter of the artery was the smallest one which represents one of challenges in the reconstruction surgery and it was a good lesson for judging the pedicle selection with great impact in our surgeon success in real life.

Animal	Purpose for free flap	Harvest time (min.)	Ischemia time (min.)	Flap result	Donor site morbidity	Pedicle length (cm)	Recipient site	Artery diameter (mm)	Vein diameter (mm)	Skin paddle size of flap (cm2)
1	Cervical skin defect reconstruction	45	55	Survived	None	10	Neck	4	6.5	32
2	Cervical skin defect reconstruction	50	50	Survived	None	10	Neck	6	5	25
Mean		47.5	52.5			10		5	5.75	28.5
3	Tracheal defect reconstruction	55	40	Survived	None	9	Neck	5	7	35
4	Tracheal defect reconstruction	62	45	Survived	Seroma	15	Neck	4	6	40
Mean		58.5	42.5			12		4.5	6.5	37.5
5	Test of device for vascular anastomosis	70	80	Total loss	N/A	8	Neck	3.5	5	28
6	Test of device for vascular anastomosis	49	35	Survived	Seroma	8	Neck	4	5	32
	54.625	50	50.8333		10.25	10.25	4.5	5.84375	32.25	32

Table 1. Porcine Reconstruction Flap Model Measurement

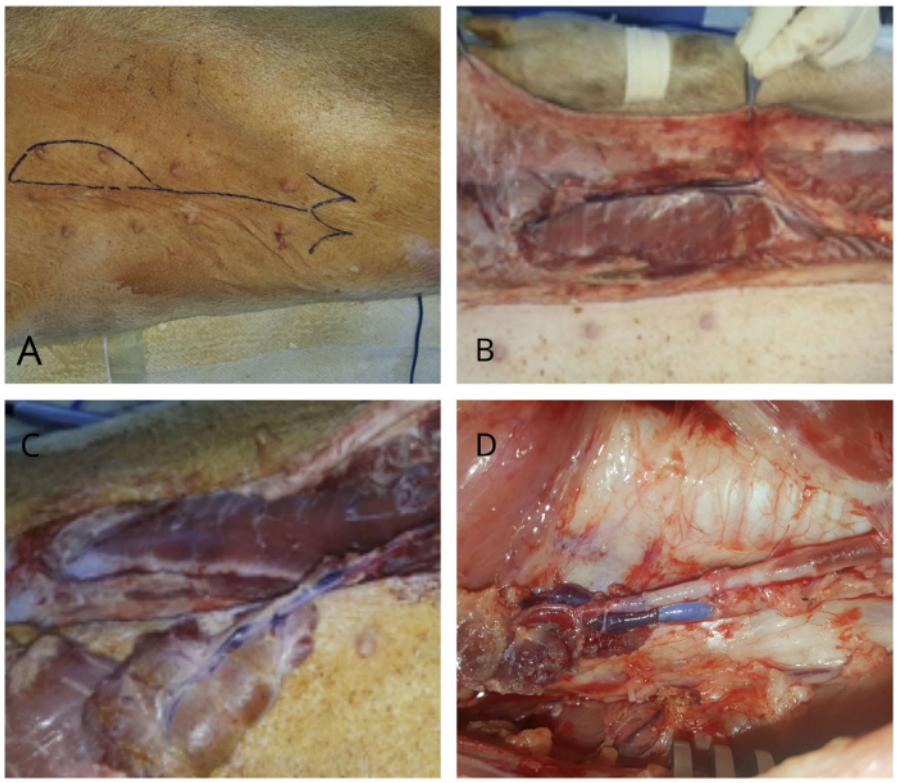

Figure 1. A porcine model SEAP flap harvesting and head and neck reconstruction. (A) The upper abdomen flapdrawing for the superior epigastric artery perforator (SEAP). (B) SEAP intramuscular dissection. (C) The flap contained the skin, subcutaneous tissue, muscle with fascia, and the superior epigastric artery with *venae comitantes*. (D) The carotid artery and internal jugular vein post anastomosis. Please click here to view a larger version of this figure.

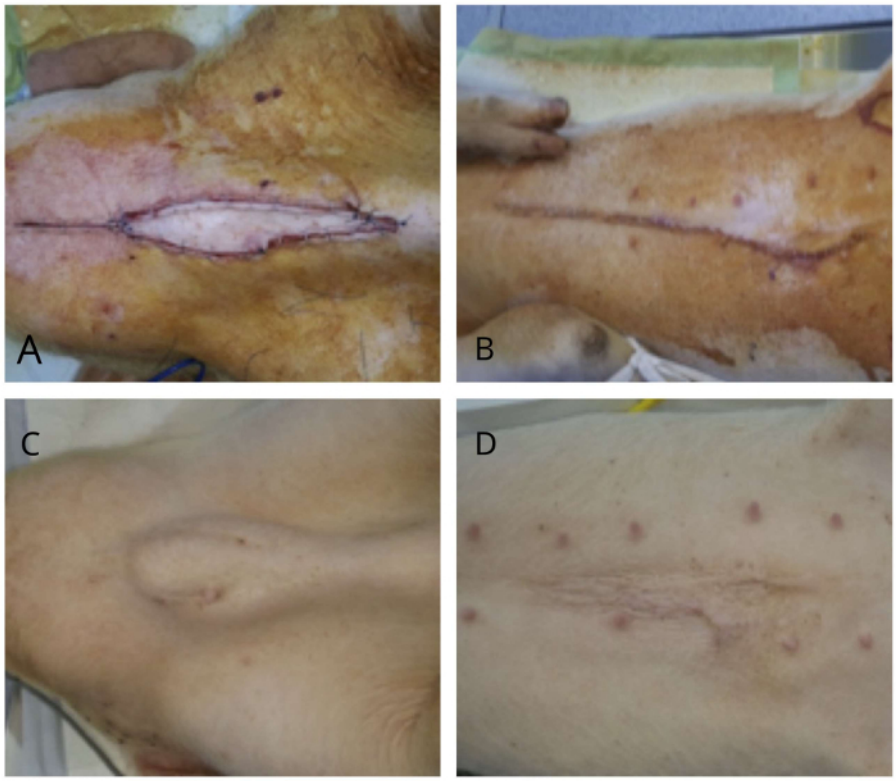

Figure 2. A porcine model after surgery and 3 months later. (A) Skin paddle of the SEAP flap after exteriorized and sutured to the cervical midline skin incision. (B) The abdominal skin incision after closure. (C) The Neck reconstruction site 3 months later. (D) The abdominal donor site after 3 months. Please click here to view a larger version of this figure.

Discussion

Significant morbidity and defects can occur in head and neck malignancy patients during surgical management. Microvascular free tissue transfer has become essential for reconstruction in most cases. The viability of the flap is a critical issue, requiring steadiness, precise handling of the pedicle, tactile sensation, visuospatial ability, and excellent operative flow from the surgeon[8]. To develop these skills, one needs extensive practice with a training model[3,4,5,6,7,8,9].

Several studies have discussed methods for learning these skills, including vascular anastomosis, which has been the focus of most studies and for which a 'microvascular practice card' was developed;[9] chickens[6,7] and rats have been used for this purpose. Human cadavers have also been used for many training courses and for estimating clinical status; e.g., reperfused human cadavers[7] were used in one study with good results. To our knowledge, there is no published study using a SEAP or DIEP flap porcine model for head and neck defects, except our study on tracheal defects, which modeled respiratory mucosa and function. The research group in France[5] used the DIEP flap, the transverse *musculocutaneous gracilis* flap, and the superior gluteal artery perforator flap for the breast reconstruction. To build on our previous study, we used the same flap for a cervical skin defect to test the procedure for vascular anastomosis and tracheal defects.

The pedicle diameter and length in the porcine model are similar to those in humans, and the overall biological similarity is sufficient to mimic clinical field conditions in humans. This exercise should improve the timing and skills necessary to accomplish the delicate harvesting and dissection of the pedicle and proper anastomosis[3,4,5,6,7,8,9]. Unfortunately, the DIEP flap, which is usually used in humans, was not applicable to this model due to its small caliber. We did not consider this a major issue because our goal was to develop skills and to recreate realistic physiological conditions with real and immediate feedback. The common carotid artery and internal jugular vein are sometimes used for microvascular anastomosis in humans, especially the internal jugular vein, which can be used for side-to-end or end-to-end anastomosis. Although the common carotid is not commonly used, the external carotid can be used in cases when other branches are injured.

Our porcine model is a living animal that, despite some anatomical differences, can reliably approximate clinical conditions in an actual surgical procedure at a lower cost than a human cadaver, and gives real feedback for microvascular reconstruction, harvesting, and anastomosis performed in the same location. Additionally, the model can help develop the dexterity, visuospatial ability, and the judgment required for these procedures.

Disclosures

The authors have nothing to disclose.

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