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Title: A Standardized Pig to Macaque Heterotopic Heart Xenotransplantation Model

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Author Questionnaire

1. We have marked your project as author-provided footage, meaning you film the video yourself and provide JoVE with the footage to edit. JoVE will not send the videographer. Please confirm that this is correct.

✓ Correct

2. Microscopy: Does your protocol require the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or something similar? **No**

3. Software: Does the part of your protocol being filmed include step-by-step descriptions of software usage? **No**

4. Proposed filming date: To help JoVE process and publish your video in a timely manner, please indicate the proposed date that your group will film here: **10/17/2025**

When you are ready to submit your video files, please contact our China Location Producer, [Yuan Yue](#).

Current Protocol Length

Number of Steps: 24

Number of Shots: 48

Introduction

INTRODUCTION:

~~What is the scope of your research? What questions are you trying to answer?~~

- 1.1. **Jiangping Song:** The research establishes a standard heterotopic xenotransplantation model to study rejection, offering consistency with orthotopic models but easier operation.

- 1.1.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera. ~~Suggested B-roll: 4.1~~

~~What technologies are currently used to advance research in your field?~~

- 1.2. **Kai Xing:** Small and large animal models, brain-dead recipient transplants, and primate recipients remain the key research models.

- 1.2.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera.

CONCLUSION:

~~What advantage does your protocol offer compared to other techniques?~~

- 1.3. **Jiangping Song:** The protocol is optimized for cynomolgus monkeys, providing size-specific adaptations compared to baboon-based transplantation techniques.

- 1.3.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera.

Ethics Title Card

This research has been approved by the Animal Ethics Committee at Fuwai Hospital

Protocol

NOTE: Protocol drafted from footage

2. Preoperative Preparation and Abdominal Access for Donor Heart Implantation in Non-Human Primates

Demonstrator: Jiangping Song

2.1. To begin, scrub the shaved areas of an anesthetized donor thoroughly with povidone-iodine [1].

2.1.1. LAB MEDIA: 68757-1 02:42-03:04

2.2. Make a midline abdominal incision with a number 23 surgical blade, approximately 12 to 15 centimeters in length [1].

2.2.1. LAB MEDIA: 68757-2-MTS 01:34-01:45

2.3. Use electrocautery to sequentially dissect through the superficial fascia, linea alba, transversalis fascia, subperitoneal fascia including extraperitoneal fat, and finally incise the parietal peritoneum to access the abdominal cavity [1].

2.3.1. LAB MEDIA: 68757-2-MTS 02:16-02:20, 04:50-05:10

2.4. Explore the abdominal cavity to assess for any adhesions between the intestines and the abdominal wall [1]. If adhesions are present, carefully dissect them using electrocautery to minimize tissue injury and reduce the risk of postoperative mechanical bowel obstruction [2].

2.4.1. LAB MEDIA: 68757-2-MTS 06:41-07:05

2.4.2. LAB MEDIA: 68757-2-MTS 08:07-08:20, 09:03-09:10

2.5. Then carefully dissect the surrounding tissues from the abdominal aorta and inferior vena cava to minimize vascular injury and bleeding [1]. Expose the abdominal aorta and inferior vena cava between the origins of the renal arteries and the iliac artery bifurcation as fully as possible [2].

2.5.1. LAB MEDIA: 68757-2-MTS 11:45-12:00

2.5.2. LAB MEDIA: 68757-2-MTS 12:25-13:30

2.6. Preserve the inferior mesenteric artery and its vein during dissection. Meticulously preserve all lumbar branches [1].

2.6.1. LAB MEDIA: 68757-2-MTS 14:38-15:00

3. Donor Heart Procurement and Cardioplegic Preservation for Xenotransplantation in Pigs

3.1. To procure the donor heart, perform a midline sternotomy to access the thoracic cavity [1]. Carefully divide the donor's sternum using a Lebsche sternum knife [2].

3.1.1. LAB MEDIA: 68757-1 14:00-14:11, 141:31-14:36

3.1.2. LAB MEDIA: 68757-1 17:51-18:10

3.2. After exposing the thoracic cavity, incise the pericardium [1] and meticulously dissect to separate the ascending aorta and main pulmonary artery [2].

3.2.1. LAB MEDIA: 68757-1 19:21-19:28, 19:55-20:08

3.2.2. LAB MEDIA: 68757-1 24:07-24:18

3.3. Place a 4-0 purse-string suture at the aortic root [1] and insert a single-use antegrade cardioplegia cannula [2]. Sequentially clamp the superior and inferior vena cava, followed by cross-clamping the ascending aorta [3]. Immediately after cross-clamping, incise the pulmonary veins and inferior vena cava to decompress the heart, ensuring incisions are large enough for drainage [4].

3.3.1. LAB MEDIA: 68757-1 26:52-27:04

3.3.2. LAB MEDIA: 68757-1 26:12-26:45

3.3.3. LAB MEDIA: 68757-1 30:28-30:35

3.3.4. LAB MEDIA: 68757-1 31:11-31:19

3.4. Immediately immerse the heart in sterile ice-cold saline to induce hypothermia between 0 to 4 degrees Celsius [1]. Suction the pericardial cavity to evacuate the residual blood [2-TXT]. Initially perfuse the donor heart with 30 milliliters per kilogram body weight of HTK solution [3].

3.4.1. LAB MEDIA: 68757-1 31:37-31:50

3.4.2. LAB MEDIA: 68757-1 32:03-32:08

TXT: Maintain perfusion pressure at 150 mm Hg using a pressure bag

3.4.3. LAB MEDIA: 68757-1 34:47-35:06

Video Editor: Please emphasize the lower right video as well

3.5. Gently elevate the heart and sequentially transect the inferior vena cava and pulmonary veins using surgical scissors [1-TXT].

3.5.1. LAB MEDIA: 68757-1 36:01-36:20

TXT: Carefully avoid injuring the superior vena cava and right atrium while dividing the right superior pulmonary vein

- 3.6. Sequentially incise the left atrium, pulmonary artery, aorta, and superior vena cava, ensuring clear margins and tissue integrity [1].

3.6.1. LAB MEDIA: 68757-1 36:51-37:07

- 3.7. Immediately immerse the explanted heart in ice-cold saline for preservation [1]. Perfuse the donor heart with University of Wisconsin solution at 30 milliliters per kilogram for superior myocardial protection [2].

3.7.1. LAB MEDIA: 68757-1 39:05-39:20

3.7.2. LAB MEDIA: 68757-1 39:57-10:15

4. Donor Heart Implantation and Vascular Anastomosis in a Non-Human Primate Recipient

- 4.1. To implant the donor heart, securely close the donor superior vena cava, inferior vena cava, and pulmonary vein orifices of the left atrium using 4-0 Prolene sutures [1-TXT].

4.1.1. LAB MEDIA: 68757-2-MTS 22:49–23:10

TXT: Administer 5000 U heparin sodium (i.v) to prevent thrombus formation

- 4.2. Place a DeBakey atraumatic tangential clamp on the recipient's inferior vena cava [1-TXT]. Then, using a double-armed 5-0 Prolene suture, begin anastomosis at the 12 o'clock position, inserting one needle from inside to outside on the recipient vessel [3].

4.2.1. LAB MEDIA: 68757-2-MTS 25:53-26:03

TXT: Create a longitudinal incision slightly larger than the donor pulmonary artery

4.2.2. LAB MEDIA: 68757-2-MTS 27:10-27:20

- 4.3. Insert one needle from the outer wall of the donor artery to the lumen [1], then insert from the outer wall of the recipient inferior vena cava to the lumen [2]. Continue with continuous suturing [3], and tie a knot after completing the anastomosis [4].

4.3.1. LAB MEDIA: 68757-2 27:10-27:23

4.3.2. LAB MEDIA: 68757-2 27:23-27:52

4.3.3. LAB MEDIA: 68757-2 30:20-31:52

4.3.4. LAB MEDIA: 68757-2 36:41-37:05

- 4.4. Partially clamp the recipient abdominal aorta using a DeBakey atraumatic tangential clamp [1]. Create a longitudinal incision slightly larger than the donor aorta [2].

4.4.1. LAB MEDIA: 68757-2 38:10-38:18

4.4.2. LAB MEDIA: 68757-2 38:23-38:30

- 4.5. Anastomose the donor aorta to the recipient abdominal aorta using the same technique

[1]. Release the DeBakey atraumatic tangential clamp to allow arterial deairing [2], and finally tie a knot [3-TXT].

4.5.1. LAB MEDIA: 68757-2 39:38-42:30

4.5.2. LAB MEDIA: 68757-2 50:44-50:49

4.5.3. LAB MEDIA: 68757-2 57:58-58:30

TXT: If ventricular fibrillation occurs, place defibrillator paddles on both ventricles and deliver a biphasic 5 J shock

4.6. Place a negative pressure drainage tube in the abdominal cavity to prevent fluid accumulation and monitor for haemorrhage [1].

4.6.1. LAB MEDIA: 68757-2-MTS 01:10:16-01:10:37

4.7. Close the abdominal wall in layers using 3-0 absorbable sutures for fascia and subcutaneous tissue, and 1-0 silk sutures for the skin [1-TXT].

4.7.1. LAB MEDIA: 68757-2-MTS 01:14:08-01:14:46, 01:23:42-01:23:49

TXT: Perform a postoperative abdominal ultrasound to assess cardiac activity

Results

5. Results

5.1. A reproducible pig-to-macaque heterotopic heart xenotransplantation model was successfully established through a series of surgical steps, culminating in the placement of the donor heart into the recipient's abdominal cavity [1].

5.1.1. LAB MEDIA: Figure 1. *Video editor: Please sequentially highlight images A to H*

5.2. Postoperative echocardiographic evaluation confirmed that the donor heart resumed contractile activity , with preserved systolic and diastolic function [1].

5.2.1. LAB MEDIA: Figure 2. *Video editor: Please sequentially highlight the images A (top and bottom) to C*

Pronunciation Guide:

❑ Heterotopic

Pronunciation link: <https://www.merriam-webster.com/dictionary/heterotopic>

IPA: /,hɛtərə'tɑ:pɪk/

Phonetic Spelling: heh-tuh-roe-tah-pik

❑ Xenotransplantation

Pronunciation link: <https://www.merriam-webster.com/dictionary/xenotransplantation>

IPA: /,zi:nɒs,ˌtrænsplæn'teɪʃən/, /,zɛn.ɒs,ˌtrænsplæn'teɪʃən/

Phonetic Spelling: zee-noh-trans-plan-tay-shun

❑ Macaque

Pronunciation link: <https://www.merriam-webster.com/dictionary/macaque>

IPA: /mə'kæk/, /mə'kɑ:k/

Phonetic Spelling: muh-kak / muh-kahk

❑ Cardioplegia

Pronunciation link: <https://www.merriam-webster.com/dictionary/cardioplegia>

IPA: /,kɑ:rdioʊ'pli:dʒə/

Phonetic Spelling: kar-dee-oh-plee-juh

❑ Hypothermia

Pronunciation link: <https://www.merriam-webster.com/dictionary/hypothermia>

IPA: /,haɪpoʊ'θɜ:rmɪə/

Phonetic Spelling: hy-po-ther-mee-uh

❑ Myocardial

Pronunciation link: <https://www.merriam-webster.com/dictionary/myocardial>

IPA: /,maɪoʊ'kɑ:rdiəl/

Phonetic Spelling: my-oh-kar-dee-uhl

❑ Anastomosis

Pronunciation link: <https://www.merriam-webster.com/dictionary/anastomosis>

IPA: /ə,næstə'moʊsɪs/

Phonetic Spelling: uh-nas-tuh-moh-sis

❑ Peritoneum

Pronunciation link: <https://www.merriam-webster.com/dictionary/peritoneum>

IPA: /,pɛrətn'i:əm/

Phonetic Spelling: pair-uh-tee-nee-um

❑ Mesenteric

Pronunciation link: <https://www.merriam-webster.com/dictionary/mesenteric>

IPA: /,mɛzən'tɛrɪk/, /,mɛsən'tɛrɪk/

Phonetic Spelling: mez-en-tair-ik / mess-en-tair-ik

❑ Sternotomy

Pronunciation link: <https://www.merriam-webster.com/dictionary/sternotomy>

IPA: /stər'nɑ:təmi/

Phonetic Spelling: ster-nah-tuh-mee

❑ Pericardium

Pronunciation link: <https://www.merriam-webster.com/dictionary/pericardium>

IPA: /ˌpɛrɪˈkɑːrdiəm/

Phonetic Spelling: peh-ri-kar-dee-um

❑ Hypothermic

Pronunciation link: <https://www.merriam-webster.com/dictionary/hypothermic>

IPA: /ˌhaɪpoʊˈθɜːrmɪk/

Phonetic Spelling: hy-po-ther-mik

❑ Echocardiographic

Pronunciation link: <https://www.merriam-webster.com/dictionary/echocardiography>

IPA: /ˌɛkoʊˌkɑːrdiˈɑːgræfɪk/

Phonetic Spelling: eh-koh-kar-dee-aw-graf-ik