Transgluteal Approach for Porcine Model Construction of Specific Hip Conditions

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Abstract

There exists no study reporting a safe and efficient approach for porcine model construction of specific hip conditions. Two pigs were sacrificed for the study of hip anatomy to explore possible approaches and 36 porcine models of irreparable acetabular labral tear were constructed to verify the feasibility and safety of different approaches. Based on the findings of the cadaveric study, three possible approaches were found: anterior approach, transgluteal approach, and posterior approach. 36 pigs were divided into three groups evenly in a random way according to the mentioned approaches they have undergone. The intraoperative findings revealed that the blood loss of the transgluteal group was the least among the three groups which had much to do with the least operative time. Although the posterior approach had similar surgical exposure with the transgluteal group, four pigs were found to have a surgical-related injury of the sciatic nerve. Additionally, operative exposure was inadequate due to larger surgical tension using the anterior approach compared with the other two approaches. In conclusion, transgluteal approach might be a suitable option for porcine model construction for its advantages and safety.

Introduction

The hip is a ball-and-socket joint that functions as the main weight-bearing joint and part of the spine-pelvic-hip complex[1–3]. Hip dysfunction caused by various hip conditions is accounted for pain, stiffness, loss of range of motion, and further reduction of life quality. With the initial disease untreated, the hip will progress to an osteoarthritic condition due to the loss of a normal biomechanical environment. Nevertheless, the pathogenesis and outcome of related treatment of the diseases like chondral lesion and labral tear remain uncertain because the clinical study is limited. Therefore, animal models are required to be established for the republication of the investigated conditions.

Pigs and human beings share high similarities from anatomic, genetic, and physiological perspectives. Due to the various size of pigs, we can choose suitable breed and age to perform different kinds of procedures in human medicine such as endoscopy, organ transplantation, catheterization, and neuroimaging[4–6], which are difficult to carry out in other animal models including rodents. Genetically, the size and composition of the porcine genome are similar to those of human beings[7]. Moreover, there is a remarkable resemblance between pigs and humans in physiologic for their similar function features of organs.

Hence porcine is favored when the animal model is required to study relevant hip diseases like osteoarthritis and osteonecrosis[8–10]. However, operative procedures are not needed for animal model construction in those researches mentioned above. As far as we are concerned, there is no study reporting a relative approach for building a porcine model of specific hip conditions including chondral lesions, labral tears, ligamentum teres injuries, and bone defect.

Our study aimed to propose a safe, efficient, and reproducible approach for the porcine model construction through the cadaveric study of hip anatomy.

Results

The estimated values mentioned above of all groups are summarized in Table 1.

Table 1
Intraoperative findings and postoperative complications of all groups

	transgluteal group	anterior group	posterior group
Operative time (min)	32.8±2.5	69.1±2.5	33.8±0.9
Blood loss (ml)	87.9±8.9	206.3±3.4	88.6±5.4
Surgical exposure	7.2±1.1	4.3±0.8	6.4±1.1
Postoperative complication			
claudication	none	none	4
chondral lesions	none	3	none
poor wound healing	none	4	2

Intraoperative Findings

The operative time and blood loss of the three groups were as followed: transgluteal group (32.8±2.5 mins, 87.9±8.9 ml); anterior group (69.1±2.5 mins, 206.3±3.4 ml); posterior group (33.8±0.9 mins, 88.6±5.4 ml). The blood loss of the anterior group was significantly larger than the posterior and transgluteal groups (P<0.001, Table 2). There was no significant difference in blood loss between the posterior and transgluteal groups. Moreover, the anterior group underwent the longest operation among the three groups (P<0.001, Table 2). The operative time of the transgluteal group was similar to that of the posterior group. The results of the rating of surgical exposure indicated the worst surgical exposure of the anterior group (P<0.001, Table 2). There showed a better surgical field of the transgluteal group than that of the posterior group despite the absence of significance (P=0.056, Table 2).

Table 2
Comparison of intraoperative findings between groups

	trans vs anterior		P-value	trans vs posterior		P-value	anterior vs posterior		P-value
Blood loss (ml)	87.9±8.9	206.3±3.4	<0.001	87.9±8.9	88.6±5.4	0.851	206.3±3.4	88.6±5.4	<0.001
Operative time (min)	32.8±2.5	69.1±2.5	<0.001	32.8±2.5	33.8±0.9	0.16	69.1±2.5	33.8±0.9	<0.001
Surgical exposure	7.2±1.1	4.3±0.8	<0.001	7.2±1.1	6.4±1.1	0.056	4.3±0.8	6.4±1.1	<0.001

Postoperative Complication

Four pigs of the posterior group were found to have claudication due to surgical-related injury of the sciatic nerve. Chondral lesions in the acetabulum were observed in three pigs of the anterior group which might be secondary to surgical injury. In addition, poor wound healing occurred in four pigs of the anterior group, two pigs of the posterior group.

Survival

As shown in Figure 6 and Table 3, the anterior group showed significantly lower one-month survival rates than the transgluteal group (0.5±0.1443 vs 0.9167±0.798, P=0.025). Although there was no significant difference, there showed a trend towards lower one-month survival rates in the anterior group compared with the posterior groups. Most deaths occurred within two weeks after surgery in all groups (three of six pigs in the anterior group and one of two pigs in the posterior group). Both two-month and three-month survival rates of the anterior group were lower than the transgluteal group (0.4167±0.1423 vs 0.8333±0.1076, P=0.026; 0.3333±0.1361 vs 0.8333±0.1076, P=0.011). There was a significant difference in two-month survival rates between the anterior group and posterior group (0.4167±0.1423 vs 0.8333±0.1076, P=0.011).

Table 3
Survival rates of each phase in all groups

Survival rates	transgluteal group	anterior group	posterior group
one month	0.9167±0.798	0.5±0.1443	0.8333±0.1076
two months	0.8333±0.1076	0.4167±0.1423	0.8333±0.1076
three months	0.8333±0.1076	0.3333±0.1361	0.6136±0.1526

Discussion

The blood loss and operative time of the transgluteal group tend to be the least, which is mostly attributed to the best surgical exposure for operation. Additionally, abnormal gait is absent in the transgluteal group during the observation indicating a good recovery of gluteal medius. As for the anterior approaches, excessive surgical tension seems to obstruct the way to operate in the hip joint leading to greater operative time and blood loss. Given the close relationship between the posterior side of the hip joint and adjacent neurovascular structures, there is a potential risk of surgical-related injury of the sciatic nerve causing claudication. Poor wound healing due to prolonged incision has occurred in both anterior and posterior groups to facilitate surgical operation.

Despite the tremendously increasing understanding of the underlying diseases causing hip pain, the pathogenesis and outcome of relevant treatment remain uncertain. Acetabular labral labrum, for example, is thought to play an important role in the maintenance of suction seal, equal distribution of hip loading, and hip joint stability[11,12]. Labral tear can alter the biomechanical environment of the hip, leading to premature osteoarthritis and hip pain[13]. With the development of the arthroscopic instrument and surgical experience, the management options have progressed from simple labral resection to labral repair and labral reconstruction over the past decades[14,15]. However, the clinical outcomes of the mentioned treatment are inconsistent with quite a few research demonstrating a comparatively high conversion rate of total hip arthroplasty[16,17]. The factors correlated with the failure rate are difficult to explore in clinical studies. Therefore, animal models are required to verify the therapeutic effect and related mechanisms. The same as labral tear, the management of chondral lesions is still a great challenge for the possibility of cartilage repair remains unknown. Other than that, the pathogenesis of specific hip conditions like femoroacetabular impingement, osteonecrosis, and osteoarthritis is required to be uncovered.

As mentioned above, animal models are required for discovering the nature of specific hip diseases including chondral lesions, acetabular labral tears, osteonecrosis, and the outcome of relevant management like osteotomy and osteoplasty for osseous abnormality and tissue repair or reconstruction for damaged soft tissues. Just as Francois et al. claimed, animal spices were chosen for model building due to its possibility of replicating the investigated condition and the similar body reaction with human beings[18]. The extensive homology between pigs and human beings makes the porcine model a possible option for scientific researches compared with other species. In addition, porcine is of sufficient size for investigators to operate since small-sized hip joints may increase the surgery difficulty. However, there exists no study introducing the relative method of porcine model construction, which could help explain numerous uncertain mechanisms that occurred in the hip joint.

Given that, we have tried to find a safe and efficient approach for the construction of the porcine model of specific hip conditions. Through our study, the transgluteal approach seems to be the best option among the three proposed approaches. Because of the anatomic relationship between the gluteus medius and hip joint, going right through the middle of the muscular part gives adequate exposure for the acceleration of the procedure, which is beneficial for time-saving and reduces blood loss. This might explain the faster recovery and low mortality of the transgluteal group as it renders less trauma and discomfort, providing a better recovery baseline among the three groups. Other than the requirements mentioned above, the constructed model was supposed to survive long enough for the development of targeted conditions[18], which should not be neglected. According to our cadaveric findings, the adjacent vascular structures are too close to avoid bleeding from surgical injury bypassing the gluteus medius anteriorly. Therefore, extra blood loss of the anterior group might lead to postoperative reduced immune function and subsequent respiratory infections accounted for the high mortality compared with the transgluteal group. Nonetheless, the autopsy was not performed to clarify the main cause of death.

Our study showed that the largest surgical tension occurred when using the anterior approach. As the gluteus medius starts from the dorsal part of the ilium and courses posterior and backward to end at the greater trochanter, the major muscular part of the gluteus medius stands in the way when we bypass it anteriorly to reach the hip joint. Over 30 minutes have been wasted compared with the other two groups, which might be blamed for the unsatisfactory survival rate and chondral lesions in our opinion. Although the posterior group's blood loss and operative time were close to that of the transgluteal group, surgical-related injury of the sciatic nerve was present. Nearly half of pigs in the posterior group were hard to lift the involved leg, making them an abnormal gait like claudication. Despite the lesser resistance of retracting the gluteus medius, the so close distance (about 1cm) between the neurovascular structure and posterior side of the hip joint makes it a great challenge to protect the sciatic nerve from injury during operation. Besides, both the anterior and posterior approaches require extending incision for exposure, which is a potential risk factor of delayed wound healing. Surprisingly, there was no muscular dysfunction of gluteus medius in the transgluteal group where the integrity of the muscular part was restored.

There still exist some limitations of our study. First, the observation period only lasts for three months and the long-term effect of the approaches remains unknown. Second, we have only chosen Chinese miniature pig as the animal model. Whether the transgluteal approach is suitable for other breeds requires further verification.

To sum up, we recommend the transgluteal approach for its several advantages: low blood loss, less operative time, fast recovery, and high survival rate. Therefore, the transgluteal approach could be a safe and efficient option for porcine model construction of specific conditions.

Methods

Participants and ethics statement

The animal protocols for this study were approved by the Laboratory Animal Welfare and Ethics Committee of Third Military Medical University (project number: AMUWEC20211776). Skeletally mature Chinese miniature pigs, weighing 20-25 kg were included in the study of porcine model construction for specific hip conditions. All methods were carried out in accordance with the National Research Council's Guide for the Care and Use of Laboratory Animals and the study was reported according to the ARRIVE guidelines.

Specimens

Two 6-month-old pigs were sacrificed to explore the anatomy of the hip including musculature, neurovascular structures, and soft tissues like capsule. We have found that there exists generally three layers of muscle group surrounding hip joints. The superficial layer lies the tensor fasciae latae, gluteus suferficidlis, quadriceps femoris, and biceps femoris (Figure 1A). Underneath the tensor fasciae latae and gluteus suferficidlis lies the gluteus medius (Figure 1B). The distal end of the gluteus medius is the greater trochanter and the dorsal end is the ilium. The gluteus profundus is exposed when flipping over the gluteus medius (Figure 1C).

As mentioned above, the hip joint lies right under the gluteus medius, which is either faced or bypassed when the superficial layer of muscle groups is incised for exposure. We have found that both going anterior and posterior to the gluteus medius can reach the central compartment (Figure 2B, D). We have also considered bluntly dissecting the muscular part and going right through the middle of the gluteus medius, which provides the best operative exposure and the least surgical tension (Figure 2C). Based on the cadaveric finding, we have come up with three possible approaches to build a porcine model: anterior approach, transgluteal approach, and posterior approach.

The potential risk of each approach

The most vital neurovascular structure including sciatic nerve, arteria femoralis caudalis, and posterior femoral vein courses along the dorsal side of the gluteus profundus and is covered by gluteus medius (Figure 3A, B). The distance between the neurovascular structure and the posterior side of the hip joint is approximately 1 cm (Figure 3C). Therefore, using the posterior approach might increase the chance of main neurovascular structures injury, especially the sciatic nerve. As for the anterior approach, it was noted that various vascular branches were against and cut off for exposure when each layer of muscles were incised to reach the central compartment (Figure 3 D, E, F). Thus extra blood loss would possibly be the underlying risk of the anterior approach. Despite the lower risk of neurovascular injury in transgluteal group based on the cadaveric findings, there might be a potential risk of muscular dysfunction in transgluteal approach.

Animals

36 Chinese miniature pigs (6 months old of age and weighing 20-25 kg) were evenly divided into three groups in a random way according to the undergone approaches: anterior, posterior, and transgluteal group. All groups of pigs were used as models of irreparable acetabular labral tear and received subsequent treatment of labral reconstruction.

Positioning

The porcine is placed in a lateral position on an operating table and surgical incision is marked (Figure 4A).

Graft preparation

An autogenous Achilles tendon graft is used for this technique. A longitudinal incision is made posterolateral to the ankle in line with the long axis of the tibia. The lateral haft is harvested along the Achilles. The length of harvested graft is supposed to be about 15 mm. Any remaining muscular or fatty tissue is cleared after graft harvest. Because of the initial tubular shape of the Achilles tendon graft, the step of graft tubularization using sutures is skipped. (Figure 4B)

Surgical technique

The pigs were anesthetized by inhaling isoflurane with a concentration of 2.5-3%. After skin disinfection and draping (Figure 4C), a straight incision was made directly above the greater trochanter. The skin, subcutaneous superficial fascia, and aponeurotic fascia were incised. Tensor fasciae latae was incised between tensor fasciae latae and quadriceps femoris to expose the gluteus medius (Figure 5A). The transgluteal group underwent blunt dissection of the musculus gluteus medius to reach the capsule. Meanwhile, gluteus medius was pulled anteriorly or posteriorly with a retractor for exposure in the anterior and posterior groups (Figure 5 B, C, D). Following that, the gluteus profundus was exfoliated to incise the capsule and the labrum was exposed (Figure 5 E). A 1.0 cm-long anterior labrum was resected and the labral defect was reconstructed with the prepared graft secured to the acetabular rim using nonabsorbable 3-0 sutures (Ethicon) (Figure 5F).

Postoperative rehabilitation

Postoperatively, the pigs were injected with penicillin intramuscularly twice to prevent infection. There is no weight-bearing restriction or immobilization during the recovery period.

Evaluation of safety and efficiency

All pigs were followed up until three months postoperatively, at which time points the surviving pigs were sacrificed. Intraoperative blood loss and operative time of all pigs were recorded. Surgical exposure was rated from 0-10 points, where10 stands for an excellent operative field, and 0 means exposure is absolutely not enough for operation. At the endpoints of follow-up, any postoperative complications were recorded and survival curves were analyzed.

Statistical Analysis

All statistical analyses were performed with SPSS (version 21, SPSS Inc, Chicago, IL) and GraphPad Prism 7.0 software (GraphPad, La Jolla, CA, USA), and a P value<0.05 was considered statistically significant. Continuous values were compared between two groups with 2-tailed Student t-tests. Survival curves were analyzed using the Kaplan-Meier method and compared with the long-rank test.

Declarations

Acknowledgement

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Author contributions

Tiao Su and Guangxing Chen performed most of the experiments; Tiao Su performed data analyses and wrote the initial manuscript; Guangxing Chen critically edited the manuscript; Liu Yang supervised the work.

Data Availability

The data that support the findings of this study are available upon request from the corresponding author.

Competing Interests: The authors declare no competing interests.

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Figures

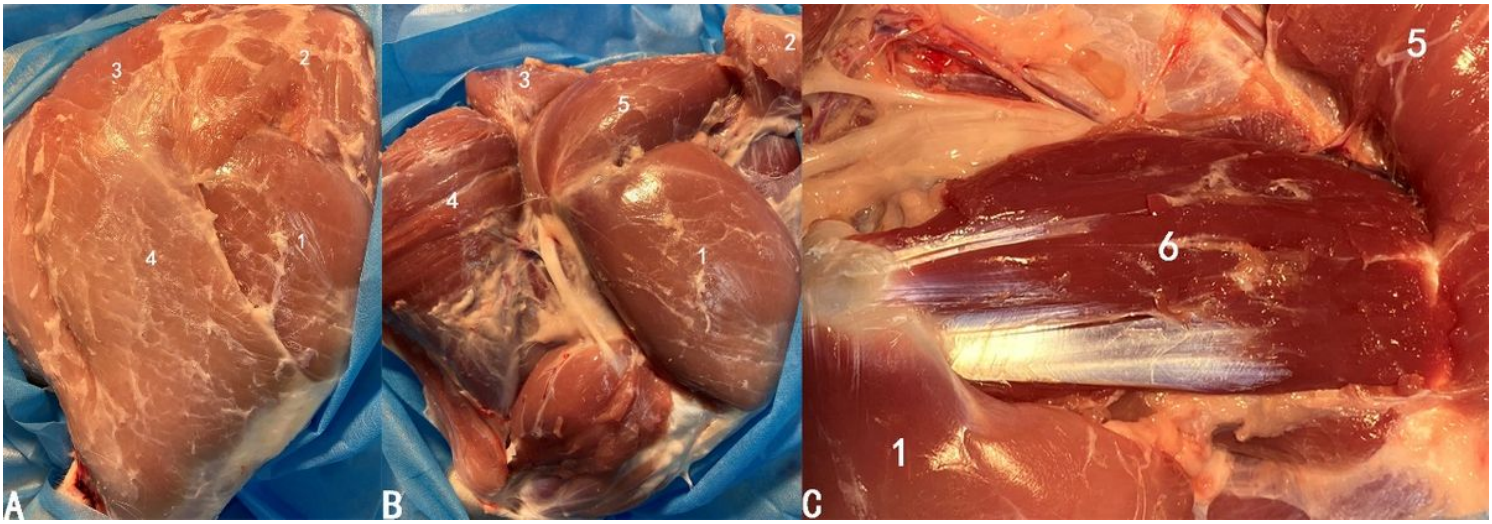

Figure 1

Muscle groups around the hip: (A) The superficial layer. (B) The second layer. (C) The third layer. (1) Quadriceps femoris. (2) Tensor fasciae latae. (3) Gluteus suferficidlis. (4) Biceps femoris. (5) Gluteus medius. (6) Gluteus profundus.

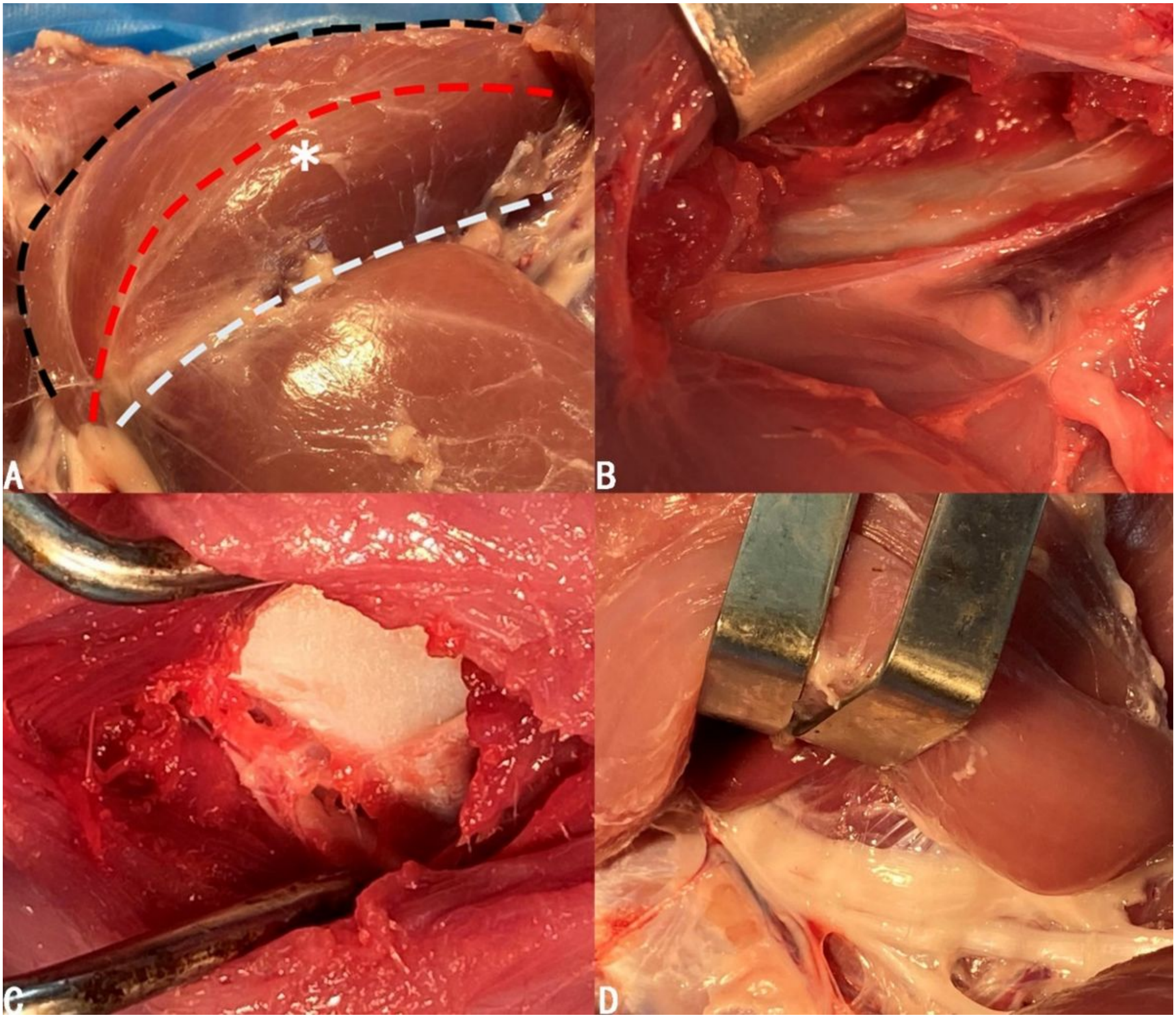

Figure 2

(A) Three possible options to reach the hip joint when facing against the gluteus medius (asterisk): anterior (white dotted curve), transgluteal (red dotted curve), and posterior (black dotted curve). (B, C, D) Viewing from anterior, intragluteal, and posterior approaches in order.

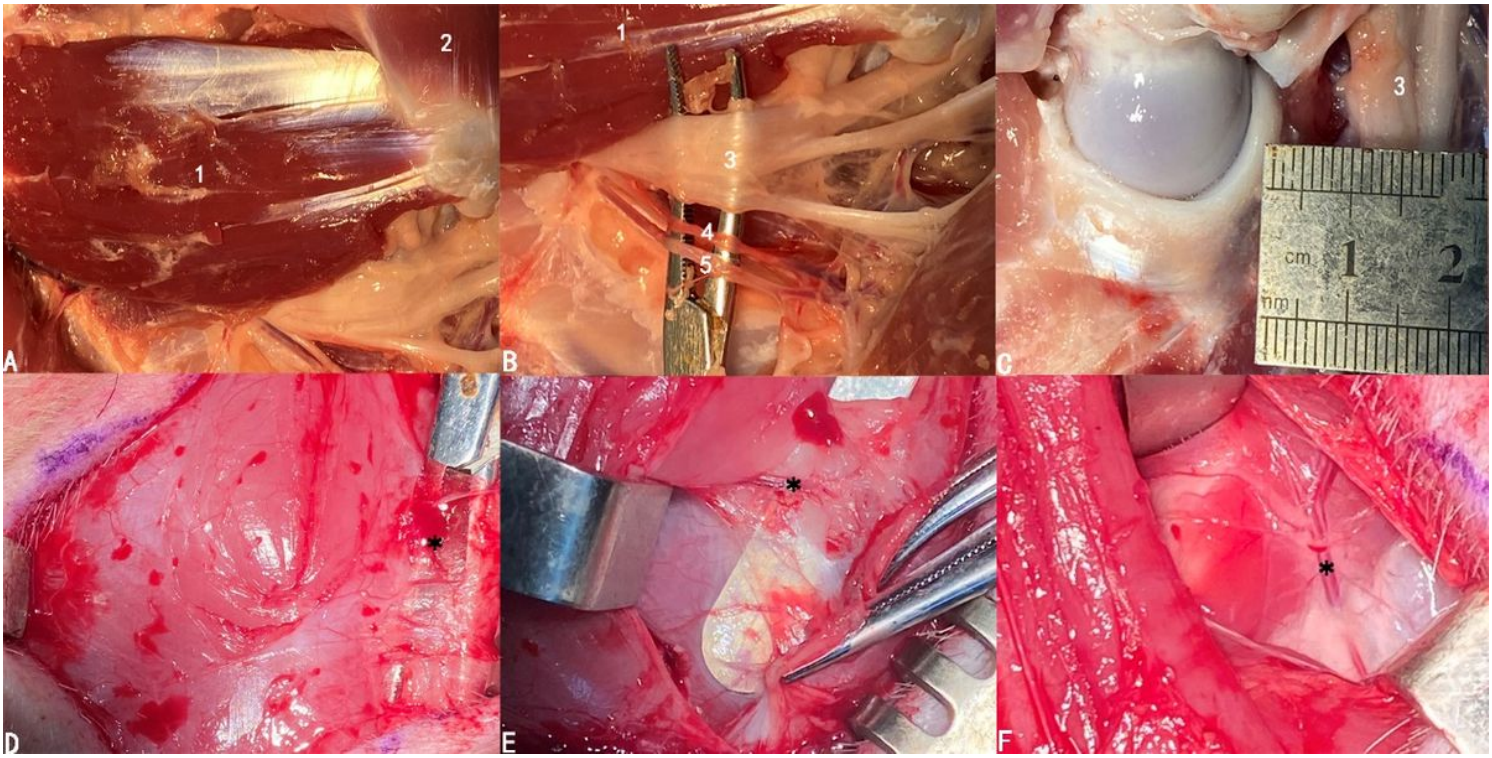

Figure 3

(A) The neurovascular structures of the posterior side of the hip joint. (B, C) The neurovascular structures lie right next to the gluteus profundus and caution must be paid during the procedure due to the close relationship between the hip joint and neurovascular structures. (D, E, F) Relevant vascular structures (black star) of each layer when using the anterior approach. (1) Gluteus profundus. (2) Quadriceps femoris. (3) Sciatic nerves. (4) Arteria femoralis caudalis. (5) Posterior femoral vein.

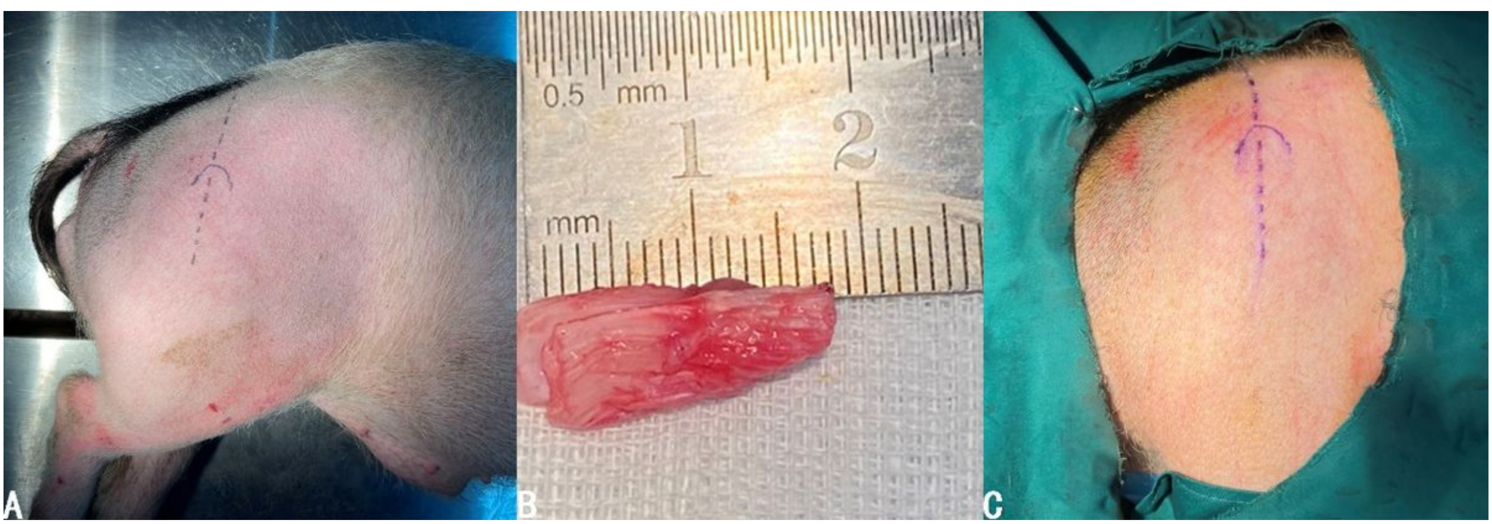

Figure 4

(A) Positioning and surgical incision marking of pigs for operation. (B) Surgical draping. (C) Harvesting of the autologous graft.

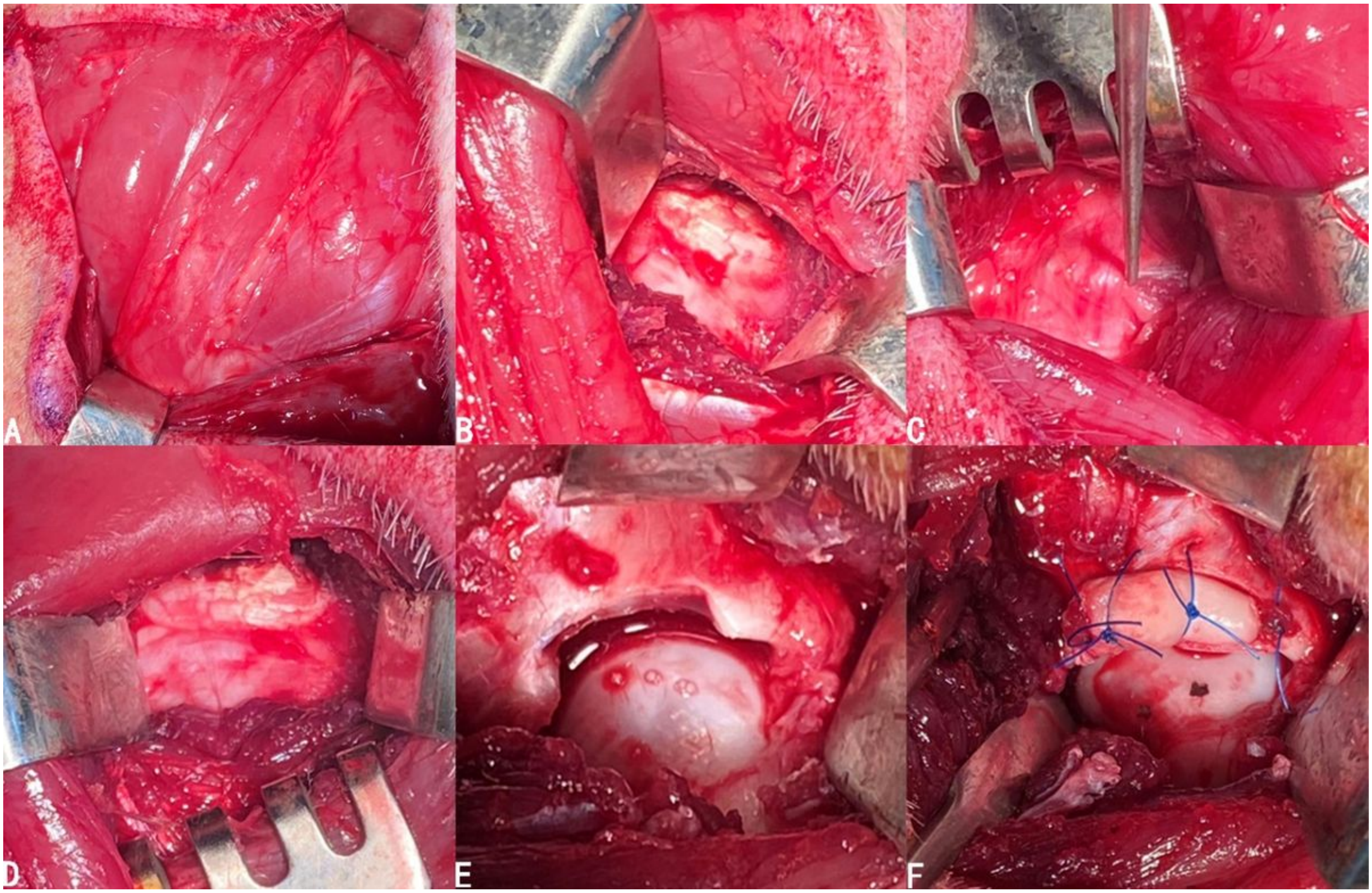

Figure 5

Surgical procedures of model construction: (A) Exposure of the gluteus medius. (B, C, D) Going anteriorly, posteriorly, and right through the gluteus medius to reach the central compartment. (E) Labral defect after labral resection. (F) The following reconstruction with prepared graft secured to the acetabulum rim.

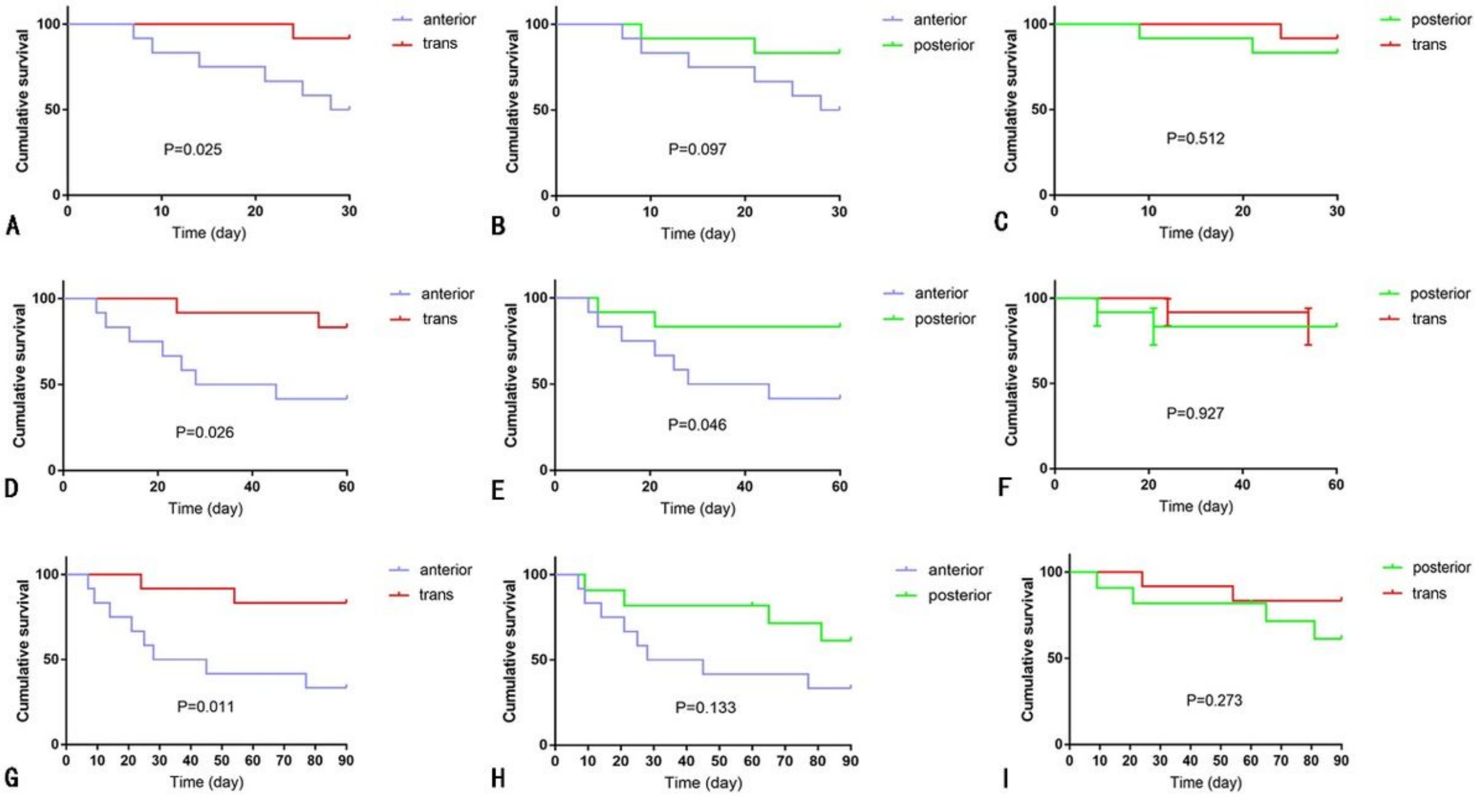

Figure 6

Comparison of cumulative survival curves in each phase: one month (A, B, C), two months (D, E, F), three months (G, H, I).