ENDOSCOPIC-ASSISTED HARVEST OF GRACILIS MUSCLE IN PIGS. A MODEL TO LEARN AND PRACTICE ENDOSCOPIC TECHNIQUES

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ENDOSCOPIC-ASSISTED HARVEST OF GRACILIS MUSCLE IN PIGS. A MODEL TO LEARN AND PRACTICE ENDOSCOPIC TECHNIQUES (Abstract): Background: gracilis muscle is a versatile choice for soft tissue coverage and for functional reconstruction in brachial or facial palsy and in fecal or urinary incontinence. Traditional harvest with large incisions results in increased donor-site morbidity with pejorative effect on overall outcome. Endoscopic-assisted gracilis harvest decreases the associated morbidity and increases patients’ satisfaction. Endoscopic plastic surgery has specific technical prerequisites. Achieving proficiency requires learning and practicing on a proper model. The aim of this study is to evaluate the swine gracilis muscle as a model for learning and practicing the endoscopic techniques. Material and methods: twenty-six gracilis muscle flaps (20 bilateral and 6 unilateral) were endoscopic-assisted harvested in 16 pigs, using single incision for each muscle. Operating time, accidents and complications were recorded. Muscle survival was evaluated half hour after operation and after one week (for eight muscles). Results: mean operating time was 118 minutes (range 75-210 minutes) and pedicle endoscopic-dissection time decreased from 45 to 10-15 minutes. The learning curve of operating time versus cases revealed fast initial improvement that gradually reached a “plateau”, with increased practice. Initial longer operating times decreased to almost one third over the last cases. Retrospectively, overall operating times between endoscopic (“plateau” phase) and classic muscle harvest are similar. Injury of one vena comitans occurred in first 4 cases with no effect on muscle survival. Eight muscles were viable at one-week follow-up. Muscles, pedicles, and nerves lengths ranged from 14/9 cm to 18/13 cm, 2.5 to 5 cm and 4 to 7 cm, respectively. Four seromas developed in the absence of drainage, but postoperative course was uneventful with quick recovery. Conclusions: Endoscopic-assisted harvesting of the swine gracilis muscle is a safe, reliable and cost-effective technique, comparable to classical harvesting method. It is a complex learning experience that combines rapid progress in skill with constant refinements. Therefore, endoscopic-assisted harvesting of the swine gracilis muscle it is an excellent model to learn and practice the endoscopic techniques.

KEYWORDS: ENDOSCOPY, GRACILIS, FLAP HARVESTING, RECONSTRUCTIVE SURGERY, TRAINING MODEL

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† received date: 06.09.2010
accepted date: 04.10.2010
INTRODUCTION
Muscle flaps are versatile tools in soft tissue reconstruction and cornerstone in restoring motor function. Gracilis muscle is the first choice in functional reconstruction of brachial or facial palsy [1-5]. Traditional harvesting method involves long incisions, amenable to increased postoperative pain, wound-related problems, longer recovery, conspicuous scar and hypoesthesia. Patient’s satisfaction relates to overall reconstruction result and donor-site morbidity has pejorative feedbacks. Increased patient expectations trigger plastic surgeons to overcome the drawbacks of the traditional harvesting method [6-7].

Endoscopic plastic surgery is a relatively new but promising field [8]. Scarce reports advocate endoscopic-assisted gracilis harvest as a better alternative, provided following criteria are achieved: shorter incision and operative time, fewer complications, similar costs and successful rates. Smaller incisions effectively decrease postoperative pain, lower the wound-related morbidity and the recovery time, improve cosmesis and increase patient satisfaction. On the surgeon side, the technique has a steep learning curve [9-14]. However, endoscopic plastic surgery is technically challenging and learning opportunities are less common. New learning models are required in order to achieve proficiency [15]. In our experience, swine model is suitable for hands-on learning of surgical techniques, due to similarities to human anatomy and to the live tissue dissection conditions reproducing real operations [16,17].

The aim of the present study is to establish a training model for endoscopic-assisted muscle harvesting. The perioperative and follow-up data are collected and learning curve is analyzed. Endoscopic operating times are compared to classical harvesting operating time database.

MATERIAL AND METHOD
Operative instruments: In addition to instruments used for classic harvest, we used 10 mm and 5 mm standard - 30 degrees angle - rigid endoscope, camera box, video camera, light source, cord, high resolution video monitor, video recorder (Stryker endoscopic cart), electrocautery, dissectors, clip appliers, suction and internal Emory-type retractors [18].

Animal experiments were approved and conducted by the Joint Committee for Animal Research and Animal Care and Ethic Committee of Pius Branzeu Center in Timisoara and Center for Simulation and Training in Surgery in Iasi. Animals were housed and treated in accordance with the “Guide for the Care and Use of Laboratory Animals”, published by the National Academy Press (US National Institute of Health Publication No 85–23, revised 1996). The animals were caged individually in the animal facility of the research center, with 12 hourly day/night cycle and with food and water ad libitum.

A total of 16 pigs (mean weight 25.4 kg, range 18-38 kg) underwent endoscopic-assisted harvest of 26 gracilis muscles (20 bilateral and 6 unilateral). They were fasted for 12 hours before surgery. Pre-anesthesia and sedation were achieved with ketamine (10-15 mg/kg) and midazolam (0.5 mg/kg) or diazepam (2 mg/kg). Muscle relaxation was induced with thiopental (5-10 mg/kg) and the pigs were intubated. Anesthesia was maintained with halothane 1-2% mixed with oxygen 2-4L/min. Isotonic solutions were perfused 5-10 ml/kg/h [19].

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Operating room setup: The pigs were positioned supine with abduction of the thigh and flexion of the knee [20,21]. The operator stood between the pig’s hindlimbs at the end of operating table, with the assistant beside him. The assistant managed single-handed maneuvering of the retractor and endoscope. The video monitor was placed at the opposite end of the operating table.

Landmarks: On the medial thigh, the saphenous bundle was identified as the distal landmark of gracilis muscle dissection; it runs caudally and posteriorly, from anterior thigh towards the posterior aspect of the knee, (Fig. 1). With the hindlimb abducted and extended, the cephalic (anterior) border of the gracilis muscle was marked as the anterior skin fold running from midline towards the knee, on the medial aspect of the thigh. Less obvious, gracilis caudal (posterior) border was palpated towards the posterior aspect of the thigh and marked, from midline to the knee. Muscle origin was drawn beside the midline and the insertion was drawn distal to the saphenous bundle on the tibia, completing the muscle flap design.

The 3 to 4 cm skin incision was marked at the muscle posterior border, 2 to 3 cm medial to the saphenous bundle [20,21].

The anatomy of swine gracilis muscle:
Gracilis is a superficial adductor located on the medial side of the thigh, between the origin on the pubic arch and the insertion in the upper tibia (via a broad aponeurosis); it is a thick, short, quadrilateral-shaped muscle. Thin musculocutaneous perforators supply the loose overlying skin, through well-defined deep fascia and minimal subcutaneous fat. Gracilis undersurface is in contact with the adductor and semimembranosus muscles. The easily palpable saphenous bundle crosses the muscle proximal to the insertion.

The gracilis is Mathes and Nahai type II muscle, with one dominant and one minor pedicle. The dominant pedicle consists of medial circumflex femoral artery (branch of the deep femoral artery) and the paired venae comitantes of 1-1.5 mm diameters. It penetrates the gracilis at the midpoint of the cephalic border after coursing distally along the muscle belly for 3 to 4 cm.
The minor pedicle is small and not critical for muscle survival. Motor innervation is provided by a branch of obturator nerve, sometimes accompanied by a smaller branch situated slightly cranial [20,21].

**Harvesting technique:**
After the anesthesia, the hindlimb was prepped and draped. Skin was incised according to pre-operatory drawing. Immediately under thin subcutaneous layer, the caudal border of gracilis muscle was identified (Fig. 2). Dissection proceeded under direct visual control above and below the muscle. The muscle was freed from loose overlaying skin and the underlying muscles and the cutaneous branches or small perforators were cauterized. When direct vision became limited, the endoscope was inserted and the remaining of the harvest (dissection, vessels ligation, muscle release, pedicle dissection and section) was performed under magnified visual control on the monitor.

Once the superficial aspect of the gracilis was free, dissection proceeded to the muscle undersurface, from distal to proximal. The cephalic border near the saphenous bundles required careful dissection due to the minor pedicle and several perforators necessitating ligation. The remaining of this border was easily detached from the underlying muscles up to the muscle origin. While proceeding proximally with the dissection, the pedicle was noticed coursing on the muscle undersurface. The caudal border was released, from distal to proximal, leaving the muscle holding on the origin, insertion and pedicle. With the pedicle held in between the long horns of Czerny retractor, straightforward dissection through the underlying muscles allowed adequate vessels length, up to the origins of the medial circumflex femoral artery and vein. The obturator nerve was identified slightly cranially to the vessels.

Distally, the muscle was safely severed 2-3 mm proximal to the saphenous bundle. The muscle insertion was transected, taking care not to injure the pedicle in the uppermost area. At this point, the muscle was attached only by its pedicle. Muscle viability and pedicle pulsations were confirmed by endoscopic inspection, 30 minutes later. The pedicle was clipped and sectioned to the desired length and the muscle was delivered through the incision.
After checking the donor site for bleeding, the incision was closed by separate absorbable 3.0 stitches. Operating times, complications and muscle anthropometric measurements were documented. Neither drains nor dressings were used; antibiotics and analgesics were administered for 3 days.

**Follow-up** was managed for 8 muscles: after 30 minutes inspection, the gracilis was stitched to the underlying muscles, the incision was closed and the pigs were returned to animal facility. Vital signs, ambulation and feeding habits were recorded daily. One week later, under general anesthesia, the incision site was reopened and the muscle viability was checked and the complications were noted.

**Statistics:** student t-test was used to analyze the classic and endoscope-assisted operating times. p<0.05 means statistically different values.

**RESULTS:**

**Endoscopic-assisted gracilis harvest:** Twenty-six gracilis muscle flaps (20 bilateral and 6 unilateral) were endoscopic-assisted harvested in 16 pigs, using single incision for muscle and pedicle dissection and muscle retrieval. Eight muscle flaps were followed-up for one week. Mean operating time was 118 minutes (range 75-210 minutes). Initial longer operating times decreased to almost one third over the last cases (Table 1).

The operating times were fitted with a logarithmic curve to reveal the trend in general (Fig. 3). The straight dotted lines are linear regressions of cases 1-10 and 11-26. The learning curve of operating time versus cases number revealed fast initial improvement that, however, gradually reached a “plateau”, as the individual experience accumulates. With constant practice, pedicle endoscopic-dissection time decreased from 45 to 10-15 minutes.

Intraoperative minor accidents occurred in the first 4 cases (injury of one vena comitans); however, all muscles were alive after 30 minutes observation.

Muscles lengths ranged from 14/9 cm to 18/13 cm, vascular pedicle varied 2.5 – 5 cm with longer nerve, 4 – 7 cm (Fig. 4).
Endoscopic-assisted gracilis muscles harvesting in swine model*.

<table>
<thead>
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<th>No.</th>
<th>Pig</th>
<th>Weight (kg)</th>
<th>Side</th>
<th>Operating time (min)</th>
<th>Intraoperative complication</th>
<th>Follow-up</th>
<th>Complications</th>
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*Legend: L – left; R – right.

First day after surgery, all animals resumed ambulation and feeding habits, minimal functional impairment was noticed for 1-2 days postoperatively. At 1 week
follow-up, eight muscles were still viable with pulsating pedicles. However, 4 non-infected seromas at the donor site were observed (nota bene: no drainage used), with normal skin color.

Prior to the study, the operator and the assistants were instructed in swine gracilis muscle classical harvesting, during live-tissue dissection training courses or teaching sessions held by the senior surgeons (MI and DP). There was no control group constituted for the comparison between the classical and endoscopic techniques. However, classical method operating times, retrospectively reviewed, showed a mean of 86 minutes (range 75-98 min). When compared to endoscopic-assisted method, classical harvesting exhibited significantly different operating times (p=0.001), but not different from the endoscopic “plateau” phase. (p=0.17).

DISCUSSION

Gracilis muscle is a versatile option for soft tissue reconstruction and for functional reconstruction in brachial or facial palsy and in fecal or urinary incontinence [1-5,22-28]. The classical harvest (straightforward and easy to learn) requires large incisions (Fig. 5) for pedicle and muscle access, sometimes up to the insertion around the knee. Short-term drawbacks include increased postoperative pain, higher chances for wound-related problems and longer recovery. On a long-term evaluation, almost half of the patients complain of conspicuous scars and thigh hypoesthesia (caused by inadvertent sensory nerve injury). Increased patients awareness points the donor-site morbidity as a critical factor when evaluating the overall results [6-7].

Starting back in 1990, the plastic surgeons adhered to endoscopic techniques and several reports mentioned endoscopic-assisted muscle harvest for latissimus dorsi, rectus abdominis, gracilis, tensor fascia lata, rectus femoris, external oblique and gastrocnemius. The endoscopic harvest can be chosen over classical ones, provided criteria are fulfilled: shorter incision and operative time, fewer complications, similar costs and success rates. Endoscopic-assisted gracilis harvest is a very good example as most of the authors achieved these criteria. Smaller incisions resulted in decreased
postoperative pain, lower rate wound-related morbidity, shorter recovery time and increased patient satisfaction. Authors agreed on endoscopic harvest having a steep learning curve [9-14, 29-36].

![Fig. 5: Large incision for classical harvesting of gracilis](image)

Endoscopic plastic surgery is a relatively new field and targets a much smaller patients sample [14]. Unlike other endoscopic surgical specialties, it is not a golden standard and learning and training opportunities are less common.

Therefore, it is the aim of the present study to establish a training model for endoscopic-assisted muscle harvesting. We favor the swine live tissue models, due to hands-on experience accumulated during the live-tissue dissection training courses [16,17]. Swine gracilis has similar anatomy to human counterpart in terms of origin, insertion, vascularization and innervation. Different anthropometric features between quadruped pig and biped humans make it a thick, short and quadrilateral-shape muscle in pigs, compared to long and thin in humans.

In clinical situations, the small incision (in the groin crease or slightly distally) allows pedicle dissection under direct vision control; the endoscopic dissection continues distally until required size is achieved and the tendon is sectioned under endoscope control, sometimes using a second incision around the knee [20,21].

For the pig gracilis, a different approach was chosen. The rationale was not to accurately reproduce the technique used in humans, but merely develop a model for training. Operation was performed through single distal incision and dissection proceeded proximally, using the retractors to create the optical cavity. The pedicle was dissected under endoscopic control. The first author was the operator for all cases, to avoid biased results.

He had no prior endoscopic surgery experience but received brief theoretical instruction on endoscopic surgery principles, techniques and instruments correct usage.

The overall learning process exhibited a biphasic mode, with the early phase (up to case 10) characterized by rapid learning of the required skill, that resulted in fast decrease in operating time; it is like “learning the ropes” phase. In the later phase (cases after 10), as the surgeon became skillful, the learning mode shifted to fine-tuning of operational details that resulted in smaller but steady decreases in operating time; with
each case the surgeons is refining his approaches and skills; it is like “mastering the skill” or “perfecting the art” phase.

Expectedly, few variables appeared in the learning process. Each one of four assistants was randomly assigned to be a part of the team. Their background was not similar, two of them were residents in surgical specialties and the other two were medical students. For the first cases the operator held the endoscope and used dominant hand for dissection while the assistant was creating the optical cavity using retractors. Soon, as the team became more cohesive and familiar with the operation, the assistant took over the camera and the retraction leaving only the harvesting for the operator. Starting with the case 12, the self-mounted Emory-type retractor was used by the assistant. Variables did not impair the improving trend of the learning process: operating times did not vary more than standard deviation with each case and the technical improvement did not affect the “plateau” phase. As the endoscopic facility was preexistent, endoscopic-assisted harvesting was performed with similar costs as traditional method.

The subcutaneous optical cavity (type 4 according to Eaves) differs from laparoscopy (virtual cavity), and arthroscopy or thoracoscopy (preexisting supporting structure); moreover, the rigid endoscope is poorly adapted to the body contours [15,18]. Dissection initiates the optical cavity and the continuous mechanical retraction maintains it while dissection proceeds, against diverse tissue requirements or constraints. These procedures need eye-hand, left hand-right hand and operator-assistant coordination to provide adequate retraction and tension for dissection. Therefore, type 4 optical cavity is more challenging and the assistant becomes a very important team member - “it takes two to tango”.

The aim of the study was not to compare the classic and endoscopic techniques; there was no control group constituted and, therefore, no complication rate comparison available. However, the almost 3-fold decrease in endoscopic operating time asked for a comparison. Retrospective classical operating times were reviewed and analyzed and classical vs. endoscopic operating times evaluated. With practice, the endoscopic-assisted harvesting became similar with classical method.

In terms of Eaves criteria [14], endoscopic-assisted gracilis muscle harvest provides shorter incision (Fig. 5), similar operating times, success rates and costs.

CONCLUSIONS

Endoscopic-assisted harvesting of the swine gracilis muscle is a safe, reliable and cost-effective technique, comparable to classical harvesting method. It is a complex learning experience that combines rapid progress in skill with steady refinement of the skill. With practice, mastering the skill builds a cohesive operating team beyond technical constraints. Therefore, endoscopic-assisted harvesting of the swine gracilis muscle it is an excellent model to learn and practice the endoscopic techniques.

DISCLOSURE: In conducting this study, none of the authors had any kind of financial/material support and/or endorsement from any medical company from Romania or abroad.

ACKNOWLEDGEMENTS: The authors would like to acknowledge the work of Polung Yang, Ph.D., Molecular Medicine Research Center, Yu-Wen Chen, PhD, Department of Physical Therapy, Chang Gung University, Tao-Yuan, Chao-Ling Lai,
RA, Department of Orthopedics, Chang-Gung Memorial Hospital Chia-Yi, Taiwan, for their contribution to data analysis and critical comments on the manuscript. We also appreciate the continuous efforts and the valuable help of Liviu Mihai Firu M.D., Lucian Mioc M.D. Most of all we would like to thank to Adrian Avram M.D., Ph.D., and George Dindelegan M.D., Ph.D., from “Iuliu Hatieganu” University of Medicine and Pharmacy, Cluj-Napoca, Romania for their help in developing the training models in pigs since 2002.

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