Original article

The clinical role of the gracilis muscle: an example of multidisciplinary collaboration

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Abstract: The gracilis muscle is widely used in reconstructive surgery as either a pedicled or free flap for soft tissue coverage or as a functioning muscle transfer. Many studies based on cadaveric dissection have focused on the vascular anatomy of the gracilis muscle providing uncertain data about the number, origin and calibre of its vascular pedicles. Computed Tomography (CT) angiographies of 40 patients (35 males and 5 females, mean age: 63 years) have been analyzed bilaterally to perform a detailed anatomical study of the gracilis vascular supply. The main pedicle penetrates the gracilis muscle at a mean distance (± S.D.) of 10 ± 1 cm from the ischiopubic branch. Its calibre shows a mean value of 2.5 ± 0.5 mm, and it is statistically larger when directly originating from the deep femoral artery versus when arising from the artery of the adductors ($p < 0.01$). The muscle belly has a mean length of 30 ± 2.1 cm. A significant correlation between the calibre of the main pedicle and the volume of the gracilis muscle was found ($p < 0.01$). The mean number of the accessory pedicles is 1.8 (range 1-4). Based on the results of our study, a 54 year old woman suffering from a recurrent recto-vaginal fistula underwent CT angiography to plan a proximally pedicled gracilis flap. CT angiography showed that the entrance point into the gracilis muscle was located 10.3 cm distal from the pubis and that the length of the muscle belly was 28 cm. This data was useful for planning the graciloplasty, since that part of the dominant pedicle and the distal myotendineuos junction was long enough for the surgical procedure. Using this information pre-operatively surgeons could minimize the extent of dissection and avoid retrograde mobilization of the dominant pedicle, thus reducing the risk of iatrogenic damage. CT angiography could be a useful pre-operative study for the plastic surgeon when planning a gracilis flap, allowing better patient selection and providing a detailed description of the muscular and vascular structures of the thigh.

Key words: CT angiography; Vascular anatomy; Gracilis; Muscular flap; Rectovaginal fistula.

INTRODUCTION

Gracilis muscle is widely used in reconstructive surgery, either as a pedicled flap or as a free microsurgical flap. Both pedicled and free flaps can be muscular or musculocutaneos (the so- called "composite flaps").[1] As a pedicled flap, gracilis muscle can be used in perineal and vaginal reconstruction, after oncological surgery,[2] in the treatment of recurrent anovaginal and rectovaginal fistulas[3] as well in the coverage of the neurovascular bundle after vascular surgery.[4] As a functioning pedicled flap the gracilis muscle can be transferred for the treatment of anal incontinence. This technique called graciloplasty was described in the 1950's by Pickrell[5] and was revolutionized in the late 1980's by the introduction of chronic muscle electrostimulation.[6] The gracilis microsurgical free flap is commonly used in the reconstruction of upper and lower limbs, in breast reconstruction[7] and, as a free functioning flap, to restore forearm function or in dynamic reconstruction of facial paralysis.[8]

The reason why this muscle has been favored by reconstructive surgeons is that it has reliable vascular and neurological pedicles and the minimal donor-site morbidity. This muscle can also be easily harvested and its multi-fascicular innervation allows safe muscular debulking preserving contractility.[9] In the literature the neurovascular anatomy of the muscle has been investigated in relation to its use as both a muscular flap and as a myocutaneous flap, but there is no general agreement about the anatomical characteristics of its main and accessory pedicles, especially considering their origin and calibre. The aim of the present study is to evaluate the anatomical vascular features of the gracilis muscle using Computed tomography (CT) angiography in order to assess its suitability in reparative surgery of rectovaginal fistula.

MATERIALS AND METHODS

Anatomoradiological study

Analysis of the characteristics of the gracilis muscle and of its vascular pedicle was performed using CT angiography in 50 patients (40 Male, 10 Female), randomly retrieved from the archive at the diagnostic centre "Euganea Medica" (Albignasego, Padova). The patients had undergone CT examination for atherosclerotic pathology. The CT images were obtained using a 16-slice multidetector CT scanner (Lightspeed 16; General Electric medical System; Milwaukee, WI, USA) with the following parameters: thickness 2.5 mm, speed 27.5, kV 120, mA 300. The analysis and post-processing of the CT scans have been realized on workstation Terarecon 3.6.2.3 Acquarius. Ten patients were excluded from the study due to excessive modification of the vascular anatomy. CT angiographies of both inferior limbs of the remaining 40 patients were carefully analyzed, focusing on the arteries directed towards the gracilis muscle.

The following morphological parameters have been recorded: 1. length of the muscle (L), measured between its pubic and tibial attachments, 2. length of the muscle belly, measured between its proximal and distal myo-tendineous junctions 3. anteroposterior and laterolateral diameters (AP and LL) of the muscle belly, measured at the entrance point of the main vascular pedicle. An estimated volume of the muscle has also been calculated (L x AP X LL). All the measurements have been performed on both inferior limbs (80) in order to make a comparison between the sides. Moreover, the following characteristics of the main vascular pedicle have been recorded: origin, course, calibre, presence of proximal accessory pedicles, distance between the entrance point into the muscle and the pubis. The origin of the main vascular pedicle has been classified as 1. from the deep femoral artery; 2. from the artery for the adductor muscles; 3. from the medial circumflex artery of the femur. The calibre of the vessels has been measured at the entrance point into the muscle. Furthermore, the following characteristics of the accessory pedicles have been recorded: number, origin, course, calibre, and distance from the pubis of their entrance point into the muscle. The accessory pedicles easily recognizable on CT-scans and clearly directed towards the gracilis muscle have been considered.

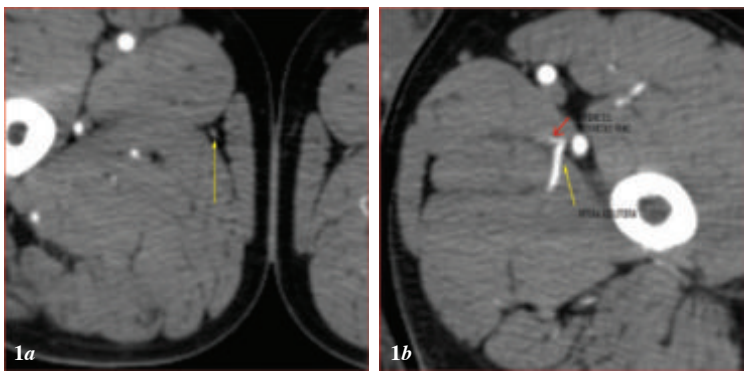

Fig. 1. – *a)* Transverse image of CT angiography at the level of the point of entry of the main pedicle into the gracilis muscle (yellow arrow). *b)* Transverse image of CT angiography showing the origin of the dominant pedicle for gracilis muscle from the artery for the adductors.

The results for each parameter are expressed in mean values (± SD) and range of value. In order to reveal correlation between the volume of the muscle and the calibre of its main vascular pedicle, and between the calibre of the main pedicle and the artery from which it originated, statistical analysis was performed by the one-way ANOVA test. $P<0.05$ was considered to be statistically significant. Statistical calculations were carried out by Prism 3.0.3 (GraphPad Software Inc., San Diego, CA, USA).

RESULTS

Gracilis muscle was identified in all the patients. It has a mean length of 41 ± 2.1 cm (37-45). The muscle belly shows a mean length of 30 ± 2.1 cm (27-34). At the entry point of its main vascular pedicle, the muscle has mean AP diameter of 44 ± 1 mm and mean diameter LL of 11 ± 2 mm.

The dominant pedicle originates from the artery for adductors in 46% of cases, in 45% of cases directly from the deep femoral artery and in the remaining cases (9%) from the medial circumflex artery. In 19% of patients the pedicles of left and right gracilis muscles originate from different vessels. The calibre of the main pedicle is quite large (2.5 mm). A correlation between the calibre of the main pedicle and its origin has been found ($p = 0.0056$): when the dominant pedicle is a direct branch of the deep femoral artery, it shows a wider calibre (mean calibre 2.7 mm) than when it is a branch of artery for adductors (mean calibre 2.3 mm).

CT angiography proved to be very reliable in following the course of the main vascular pedicle, from its origin to the deep aspect of the muscle. Independently from its origin, the main pedicle passes between adductor longus and adductor brevis muscles, reaching the deep aspect of the gracilis muscle. The entrance point into gracilis muscle was 10 ± 1.3 cm distal from the pubis. At the point of entrance into the muscle, the pedicle splits in minor branches, generally two, with opposite directions, which enter into the muscle, creating a 'hilum'. The distal branches enter into the muscle 5 cm below the most cranial ones after which the intramuscular course of the arteries is parallel to the muscular bundles. An accessory pedicle proximal to the main one was found just in 8% of cases.

At least one accessory pedicle was found in all patients. These pedicles are variable in number (1-4), with a mean of 1.8, and they originate from the superficial femoral artery or from the popliteal artery, and are directed towards the muscle passing between sartorius and adductor longus muscles. The most rostral pedicle has a mean calibre of 2 mm. No correlation has been found between the calibre of the main pedicle and the number of accessory pedicles ($p = 0.64$).

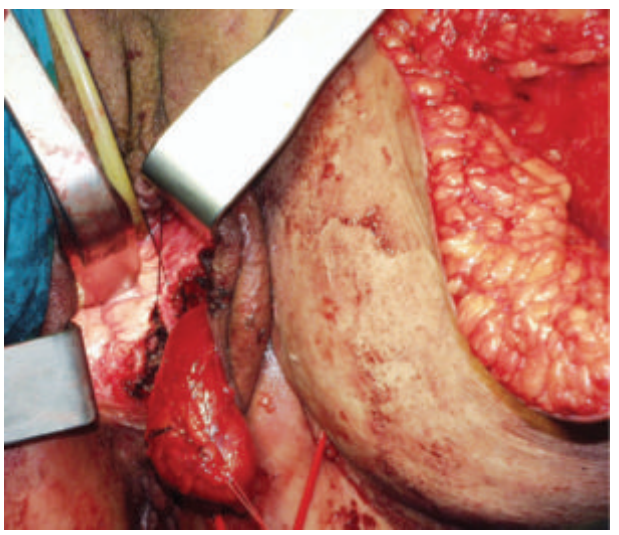

Fig. 2. – Intraoperative view of the repair of the rectovaginal fistula.

Clinical Application

Basing on the results of our study, a 54 year old woman suffering from a recurrent recto-vaginal fistula underwent CT angiography for planning a proximally pedicled gracilis flap. CT angiography showed that the dominant pedicle entered the muscle 10.3 cm distal from the pubis and that the muscle belly was 28 cm long. A transverse skin incision was made at the perineal body and dissection was performed of the rectovaginal septum to the level of at least 4 cm above the fistula. The anterior wall of the rectum and the posterior wall of the vagina were repaired with a continuous suture. The graciloplasty was performed through an inner longitudinal skin incision starting from the hypothesized point of entry of the main pedicle into the muscle and extending inferiorly on the medial aspect of the thigh. After having identified the main vascular pedicle that was located 10.3 cm below the pubis, the muscle was exposed and isolated until the distal myotendineous junction; the accessory pedicle was ligated, while the dominant one was carefully preserved. Skeletalization of the dominant pedicle was not necessary, as the muscle belly was long enough to easily reach the pelvis. Division of the branch of the obturator nerve supplying the gracilis was performed, in order to prevent muscular contraction, which could compromise the stability of the muscle in its new position. The muscle belly was turned over towards the pelvi-perineal region, passing through a subcutaneous tunnel, and easily filled the space between the vaginal and rectal walls. The muscle was fixed to the anterior wall of the rectum and to the posterior wall of the vagina with interrupted sutures. Antibiotic therapy was administered for 3 days after the surgical procedure. Long term follow-up demonstrated a stable closure of the fistula with no recurrence. Fistula closure was monitored by rectoscopy, air insufflation and periodic gynaecologic examination.

DISCUSSION

The gracilis muscle is one of the most versatile muscles used in reconstructive surgery. The anatomical features of the gracilis muscle and its pedicular arteries have been investigated in several studies performed through anatomical dissections of human cadavers [1, 10, 11] or anatomo-radiological studies on gracilis muscles harvested from cadavers.[9, 10-12] To the best of our knowledge this study is the first anatomo-radiological analysis of the vasculature of the gracilis muscle performed in vivo. We found that the anatomical features of the arteries supplying gracilis muscle can be easily identified using CT angiography. This method is both innovative and accurate as the behaviour and calibre of each vascular pedicle can be minutely determined. As regards the morphology and the size of the muscle, the results of the anatomo-radiological study are comparable to the data in literature. In fact, previous studies reported a mean length of gracilis muscle of 44-46 cm [9, 13] and of the muscle belly of 30 cm [1, 10] whereas in our study the mean values have been 41 cm and 30 cm respectively. On the contrary, the mean value of the LL diameter (1.1 cm) of the muscle has resulted significantly higher than that reported in literature (0.6 cm). This difference could be ascribed to the different trophism of the muscle in vivo and in cadavers.

From our anatomo-radiological study, the origin of the main vascular pedicle of the gracilis muscle is equally subdivided between the artery for adductors(46%) and the deep femoral artery (45%). Earliest studies and anatomical textbooks report the main pedicle as a branch of the circumflex medial artery,[9, 10, 14] whereas other publications pointed at the artery for adductors as the most common origin of the main pedicle.[1, 11] Recently, the hypothesis that these differences could have come from misinterpretation of the term "adductor artery", because many authors refer to the artery for adductors as a "transverse branch of the medial circumflex artery".[15]

In our study vascular calibres have been larger than those measured during cadaver dissections (2.5 mm vs 1.5-2 mm), probably due to the in-vivo method. The main vascular pedicle has a greater calibre when originating directly from the deep femoral artery than when it is a branch of the adductor artery; however, it is intuitive that a direct branch of a main vessel is larger than a branch of a branch artery. In 19% of patients the pedicles of left and right gracilis muscles originated from different vessels. Thus, a surgeon, planning a pedicled or free flap, could choose the left or the right muscle, according to the calibre of the main pedicle and most favourable anatomical situation.

Gracilis muscle flap is an excellent option for the repair of recto-vaginal and ano-vaginal fistulas, which are often resistant to repeated repair procedures. In fact, with a success rate increasing from 60%[16] to 83%,[17-18] this procedure has generally better outcome than those reported for other repair techniques. In particular pedicled gracilis flap is adequate in those cases of irradiated rectovaginal septum, active Crohn's disease, fibrotic perineal body, as well large and recurrent fistulas, where it is essential to separate the organs and interpose healthy tissue with an independent blood supply. In fact, the rectovaginal septum is located in an oblique coronal plane, close to the posterior vaginal wall, and shows a variable numbers of small vessels.[19] In our case CT angiography showed that the entry point into gracilis muscle was located 10.3 cm distal to the pubis and that the length of the muscle belly was 28 cm. These data were useful for planning the graciloplasty, since that part of the muscle belly between the dominant pedicle and the distal myotendineuos junction was long enough for the surgical procedure. In this way surgeons could minimize the dissection and avoid retrograde mobilization of the dominant pedicle, thereby reducing the risk of iatrogenic damage. CT angiography could be a useful preoperative study for the plastic surgeon in planning a gracilis flap, allowing a better selection of the patients and providing a detailed description of the muscular and vascular structures of the thigh.

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