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Can surface electromyography improve surgery planning? Electromyographic assessment and intraoperative verification of the nerve bundle entry point location of the gracilis muscle

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ABSTRACT

Purpose: To verify the precision of surface electromyography (sEMG) in locating the innervation zone of the gracilis muscle, by comparing the location of the IZ estimated by means of sEMG with in vivo location of the nerve bundle entry point in patients before graciloplasty procedure due to fecal incontinence. *Methods:* Nine patients who qualified for the graciloplasty procedure underwent sEMG on both gracilis muscle before their operations. During surgery the nerve bundle was identified by means of electrical stimulation. The distance between the proximal attachment and the nerve entry point into the muscle's body was measured. Both measurements (sEMG and in vivo identification) were compared for each subject. *Results:* On average, the IZ was located 65.5 mm from the proximal attachment. The mean difference in location of the innervation zones in each individual was 10 ± 9.7 mm, maximal – 30 mm, the difference being statistically significant ($p = 0.017$). It was intraoperatively confirmed, that the nerve entered the muscle an average of 62 mm from the proximal attachment. The largest difference between the EMG IZ estimation and nerve bundle entry point was 5 mm (mean difference 2.8 mm, $p = 0.767$). *Conclusion:* Preoperative surface electromyography of both gracilis muscles is a safe, precise and reliable method of assessing the location of the innervation zones of the gracilis muscles. The asymmetry of the IZ location in left and right muscles may be important in context of technical aspects of the graciloplasty procedure.

1. Introduction

Fecal incontinence is a condition which greatly influences the quality of life of affected individuals. The treatment is difficult and there is no universal method of treatment which would be suitable for all cases (Van Koughnett and Wexner, 2013). There are only a few procedures, like Sacral Nerve Stimulation (SNS) or muscle transposition techniques that give a chance for improvement in patients with end-stage incontinence, each method however has its advantages and disadvantages. In patients in whom the SNS is contraindicated, muscle transposition is the only option of surgical treatment.

Graciloplasty is one of several surgical methods of treatment of end-stage fecal incontinence, which involve muscle transposition (Barisic and Krivokapic, 2014). During this procedure one of the patient's gracilis muscles is transposed from the thigh onto the pelvic floor, to augment the weakened anal sphincters, or entirely replace them (Inglin et al., 2015). The technique involves dissection of the muscle and isolation of its body and distal tendon. The distal tendon is then cut and the muscle brought up to the perineum and wrapped around the anal canal to create a loop (either in "alpha" or "delta" configuration) (Baeten et al., 1991). The distal tendon is then sutured to either the unilateral or ipsilateral ischial tuberosity, or to skin lateral to the anus. The proximal tendon is not dissected (Rosen et al., 1998). The length of the muscle's body which can be wrapped around the anal canal is determined by the location of the most proximal neurovascular bundle, which is the main source of blood and neural stimuli to the muscle and therefore must be preserved. The surgeon is therefore able to transpose only the part of the muscle which is distal to the neurovascular entry point to the muscle's body. Taking into consideration that the distal part of the gracilis must be brought back along the thigh (folded) before forming the loop (Fig. 1), each 1 cm of increased distance between the proximal tendon and the nerve entry point means 2 cm less muscle length to construct the loop.

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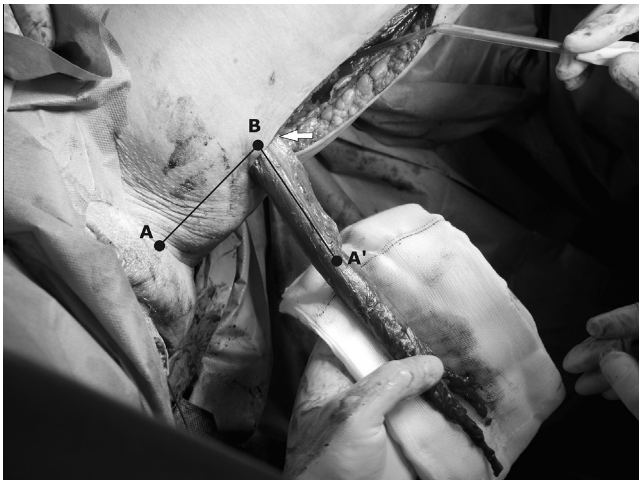

Fig. 1. Geometry of gracilis muscle transposition: (A) proximal attachment on the pubic bone, at the medial end of inguinal crease, (B) neurovascular bundle entry point to the muscle body. During the transposition, the neurovascular bundle entry point (arrow) is a pivot point for the muscle body, which means, that a large portion of the muscle (A–B, as well as A′–B) does not take part in neo-sphincter loop formation, only the part which is distal to point A′ can be used to create a neo-sphincter loop.

Although the pedicle to the profunda vessels can be dissected for increased length, excess tissue dissection increases the risk of damage to the nerve or vessels and subsequent muscle atrophy.

Previous anatomical and experimental studies have shown, that the human body is asymmetrical. In a study by Bottin et al., innervation zones of gracilis muscles were assessed by means of superficial electromyography (sEMG). In 15 healthy male subjects the location of the innervation zone of the left and right gracilis muscles were compared and significant differences were found (up to 36 mm) between left and right IZ locations in the majority of subjects (Bottin et al., 2006). The non-invasive electromyographic method described by Bottin et al. seems to be a proper tool for surgery planning, although the method has not yet been verified concerning its precision. Since the authors of this paper perform the graciloplasty procedure on a regular basis, there was an opportunity to intraoperatively measure the real distance at which the nerve enters the muscle's body, and compare it with preoperative sEMG measurements. Therefore a study was designed, to verify intraoperatively, whether the IZ location assessed by means of sEMG corresponds precisely to the location of the neural bundle entry point of the muscle's body.

2. Aim

The purpose of this study is to verify the precision of sEMG in locating the innervation zone of the gracilis muscle, by comparing the location of the IZ estimated by means of sEMG with in vivo location of the nerve bundle entry point by surgical dissection during graciloplasty.

3. Methods

The study group consisted of patients who qualified for the graciloplasty procedure. Each patient signed an informed consent prior to enrollment in the study. The patients underwent sEMG before the operation to assess the IZ location of both gracilis muscles in each individual. The assessment was performed using a linear electrode array, with 16 silver bar electrodes (5 mm × 1 mm) 10 mm apart. The alignment of the electrode array was parallel to the muscle fibers, so that each of the electrode bars was aligned perpendicularly to the muscle fibers. A standard ECG/EMG conductive gel was used as a contact agent. The signal of Motor Units Action Potentials (MUAP) was acquired and recorded using an EMG-USB2® amplifier in differential mode, with gain variable from 100 to 50,000 in 8 steps, 10–500 Hz 3-dB bandwidth, roll-off of 40 dB/decade, noise level less than 1 μV_{RMS}, sampling rate of 2048 Hz per channel (OTBioElettronica, Turin, Italy). A bandpass filter of 10–350 Hz was used for clear MUAP visualization.

The subjects would lie supine on a bed with the legs spread apart at an angle of 30° between the legs, with a Styrofoam box between their ankles, to provide resistance. The electrode array was laid along the gracilis muscle which is palpable through the skin during contraction. The proximal end of the electrode array was placed at the medial part of the inguinal crease, at the gracilis' attachment to pubic bone (considered an anatomical landmark, referenced as "proximal attachment" throughout the rest of the manuscript), so that electrode pair No. 1 and No. 2 acquired the muscle's signal 10 mm from the proximal attachment, whereas electrode No. 2 and No. 3 were 20 mm from the proximal attachment and so on, for a total of 15 electrode pairs. Proper care was taken, to avoid shifting of the skin relative to the underlying muscle, so that superficial landmarks and markings on the skin repetitively corresponded precisely with the underlying structures each time.

The subject was then asked to perform a contraction of the gracilis muscle, by adduction and inward rotation of the knees, pressing against the resistance box between the ankles. Multiple 10 s contractions of each muscle were recorded, and for each muscle, three acquisitions of the best quality (without artifacts and with proper propagation of the MUAP signal) were kept for analysis. The IZ was identified (Fig. 2) by visual inspection of the identified MUAPs (Roeleveld et al., 1997), searching for the location of the phase inversion the MUAP detected in single differential modality, and where the MUAP bi-directional propagation begins (as described by Bottin et al.) (Bottin et al., 2006). In cases where the inversion point was not visible though proper bi-directional propagation was present, the location of the IZ was assumed to be halfway between the adjacent electrodes from which the propagation began. The IZ location was marked on the skin, the distance from the proximal attachment was then measured and documented by a photograph (Fig. 3a). The choice of muscle for the procedure (left or right) was determined by the distance of IZ measured from the proximal attachment (a shorter distance meaning a longer part of the muscle available for transposition). The operating surgeon was not shown the results of the assessments, to avoid bias during intraoperative measurements.

For the surgery, the patient was placed in a supine position, with limbs fixed in the same position as during the sEMG assessment. After positioning the patient and confirming the measurements (Fig. 3b), the markings on the skin were removed before the operating surgeon could see them. During the operation the muscle was isolated in situ and the proximal nerve bundle was identified by means of electrical stimulation. The distance between the proximal attachment and the nerve bundle entry point into the muscle's body was measured and documented by a photograph (Fig. 3c). The procedure was then carried out normally.

Both measurements (sEMG and in vivo identification) were compared for each subject and the results were analyzed statistically using Friedman's ANOVA to test sEMG assessments for repeatability and Wilcoxon's matched pairs test to find statistical differences between distance assessed by means of sEMG and those measured intraoperatively. Additionally, the distance between the proximal attachment and the IZ location in the left and right gracilis muscle was compared in each subject and evaluated statistically (shorter vs longer distance).