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Episiotomy and innervation zones of the external anal Sphincter: A case series investigating the impact on neurological patterns

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ABSTRACT

Objective: To investigate the impact of mediolateral episiotomy on the innervation zones of the External Anal Sphincter (EAS) in the absence and presence of direct muscular injury.
Methods: This case series examined four primiparous women, including three who underwent vaginal deliveries with mediolateral episiotomy and one cesarean section case for reference. Pre- and post-delivery assessments utilized surface electromyography (sEMG) and endoanal ultrasound to evaluate changes in the EAS's innervation zones and obstetrical EAS injuries, alongside the Wexner score for fecal incontinence.
Results: Mediolateral episiotomy can alter the innervation pattern of the EAS, with a significant reduction in innervation zones observed in the episiotomy cases compared to the reference cesarean section case. This alteration was evident even in the absence of visible EAS injury, suggesting episiotomy's potential to disrupt EAS functionality. Notably, the Wexner score indicated varying degrees of fecal incontinence among the episiotomy cases.
Conclusion: Mediolateral episiotomy may impact the EAS's innervation pattern, highlighting the importance of considering individual innervation zones in episiotomy planning. While the integration of sEMG into routine clinical practice is still evolving, this study underscores its potential as an additional tool for assessing neural integrity, particularly in cases of anal sphincter injury and reconstruction. Future research should explore the dynamics of re-innervation and the correlation between vascular injury and reduced innervation zones to enhance patient-specific care in pelvic floor dysfunction.

1. Introduction

Episiotomy, the surgical incision made in the perineum during childbirth to ease it, has been a contentious practice in obstetrics, reflecting an evolution of perspectives over centuries. Historically, the shift from a social model of care, where midwives prioritized perineal protection and comfort, to a surgical model marked by the advent of "Man-Midwives" in the 17th and 18th centuries, transformed childbirth (Dahlen et al., 2011). This shift pathologized the perineum, making episiotomies routine as part of a broader surgical approach to perineal care.

In the last three decades, however, there has been a resurgence in approaches aimed at preserving and protecting the perineum, leading to a dichotomy in care models (Ghulmiyyah et al., 2022). Contemporary obstetric care, supported by scientific literature, now advocates for the selective use of episiotomy, reflecting a global trend towards minimizing its rate (Perrin et al., 2023).

Despite these advancements, episiotomy decisions often remain more influenced by care providers' clinical expertise than by literature evidence or women's preferences, indicating a gap in shared decision-making and a need for further research to reach consensus on episiotomy indications. The debate continues, especially around the types of episiotomy, such as mediolateral versus midline incisions, with a preference for mediolateral episiotomy to prevent obstetric anal sphincter injuries (OASIS) (Eogan et al., 2006; Marty and Verspyck, 2018).

The potential consequences of episiotomy extend beyond immediate

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surgical outcomes, particularly concerning the innervation of the External Anal Sphincter (EAS). Disruption of these innervation zones (IZs), which are the regions where the neuromuscular junctions are located, may have significant implications for anal sphincter function and long-term anal continence (Cescon et al., 2014a; Gregory et al., 2004; Merletti, 2016). The EAS is innervated from the outside, which is relevant in the case of an episiotomy because an injury to the nerve fibers approaching the neuromuscular junctions in the innervation zone (s) of the muscle's motor units (MUs) can theoretically occur without injuring the muscle itself. Surface electromyography (sEMG) has emerged as a pivotal tool in delineating the innervation of the EAS, proposing a novel, individualized approach to episiotomy (Peng et al., 2016). By identifying areas with fewer innervation zones prior to surgery, obstetricians could potentially minimize the risk of EAS damage by tailoring the episiotomy site to the patient's specific innervation pattern. However, the integration of sEMG into clinical practice remains limited, possibly due to prevailing assumptions that significant injury is primarily associated with direct muscle trauma (Enck et al., 2005; Nowakowski et al., 2017). Furthermore, despite the initial promise on the basis of the early work by Cescon et al., there has been limited dissemination and clinical uptake of this technique, raising questions about its perceived clinical relevance and the allocation of further international funding for research or dissemination (Cescon et al., 2014a; Merletti et al., 2021).

Given the historical context of episiotomy use, its debated efficacy, and the potential for altered innervation to affect anal sphincter function, this study aims to investigate the impact of episiotomy, specifically in the absence and presence of OASIS, on the innervation zones of the EAS. By focusing on this aspect, we seek to contribute to the nuanced understanding of episiotomy's long-term implications for women's health, advocating for informed, evidence-based practices in obstetric care.

2. Methods

2.1. Study Design and participants

This case series was conducted to evaluate the impact of episiotomy, specifically in the absence of OASIS, on the innervation zones of the EAS. Four cases were included: three involving vaginal deliveries with episiotomy and one cesarean section as a reference. This study followed the institutional requirements and was evaluated and approved by the Republic of Slovenia National Medical Ethics Committee (NMEC) number 124/02/10. Informed consent was signed by all participants in the study. The four cases included in this study were purposefully selected to investigate the effects of episiotomy on the innervation zones of the external anal sphincter (EAS). These cases were drawn from a broader cohort of 133 primiparous women who met the inclusion criteria of being aged 30 to 35 years, delivering at full term ($\geq$37 weeks gestation), and undergoing pre- and post-delivery assessments with endoanal ultrasound, surface electromyography (sEMG), and the Wexner score for fecal incontinence.

Among these 133 participants, 10 women were identified with anal sphincter injuries, of whom 5 had episiotomies. Two cases with episiotomy and confirmed anal sphincter injury were selected to represent patterns of innervation loss associated with severe EAS damage. One case without episiotomy or anal sphincter injury (cesarean section) was included to establish baseline innervation zone patterns before and after delivery. The final case, involving episiotomy without detectable anal sphincter injury on ultrasound, was included to examine changes in innervation zones in the absence of visible structural damage. This selection strategy ensured a targeted analysis of episiotomy's effects on neural and structural integrity of the EAS.

2.2. Data Collection and Instruments

Comprehensive pre- and post-delivery assessments were performed using sEMG and endoanal ultrasound to evaluate changes in the EAS. The sEMG was conducted to measure the electrical activity of the EAS, focusing on the amplitude of EMG signals and the distribution of innervation zones of the individual MUs across four quadrants of the anal sphincter: lower left (LL), upper left (UL), lower right (LR), and upper right (UR). The assessments were measured at two time points: pre-delivery, approximately 24 h before the onset of labor, and post-delivery, approximately 48 h after delivery. Measurements were performed using a rectal probe equipped with 16 silver electrodes developed within the EU OASIS project and used in the TASI project (Fig. 1). Temporal changes in the EMG signal registered by the electrodes reveal the electrical activity of active motor units and the way motor unit action potentials (MUAPs) are conducted along fibers of the motor units. The probe was moistened with a drop of glycerol before insertion into the anal canal to ensure slight lubrication while maintaining electrode-mucosa electrical contact for singal acquisition. The EMG probe was inserted approximately 20 mm into the anal canal, ensuring the electrode array maintained contact with the anal verge. The signals were measured three times at rest. The subject was then asked to start contracting the anal sphincter after a 10-second rest until reaching the strongest contraction within 5 s. The contracted anal sphincter was held for 10 s. The EMG signals were monitored and stored for 50 s, including 10-second and 20-second rest periods before and after the strongest contraction, respectively (Fig. 2). The EMG signal was amplified using the EMG_USB amplifier (LISiN OT-Bioelettronica, Turin, Italy). The signals were sampled at 2048 Hz and stored on a PC after 12-bit A/D conversion. Slow signals generated by smooth bowel activity (if present) were removed using a high-pass filter set at 10 Hz. sEMG was decomposed into the constituent motor unit action potential trains using the Convolution Kernel Compensation (CKC) method (Holobar and Zazula, 2007). This method was applied to EMG signals of the external anal sphincter and allowed the identification of up to 7 simultaneously active motor units. Additionally, a modified algorithm was used to characterize not only motor units but also innervation zones (Cescon, 2006).

The signals were then divided into periods of 0.5 s. For each channel and period, the average rectified value (ARV) was calculated. The ARV was determined period by period to obtain one value for each channel per period. A modified Radon transform algorithm was employed to plot the distribution of the IZs (Cescon, 2006).

The integrity of the anal sphincter complex was examined through endoanal ultrasound before and after the delivery, with a specific focus on detecting any injuries resulting from the delivery process. To evaluate the functional outcome related to fecal incontinence (FI), the Wexner Fecal Incontinence Score was employed postpartum. This scoring system quantifies the severity of FI, including the inability to retain gas, liquid, or solid stool, with scores ranging from 0 (no incontinence) to 20 (complete incontinence).

2.3. Procedures

The episiotomy, when performed, was a right mediolateral episiotomy done at a 40–50-degree angle to the midline, with a length of 3 to 4 cm. The decision to perform an episiotomy was based on obstetric indications during the delivery process. In the cesarean section case, the surgical procedure was carried out after spontaneous onset of labor, with labor augmentation using oxytocin.

2.4. Statistical analysis

Given the descriptive nature of this case series, statistical analysis focused on summarizing the EMG amplitudes, the distribution of innervation zones within the EAS, and the Wexner scores before and after delivery. Comparative analysis was primarily qualitative,

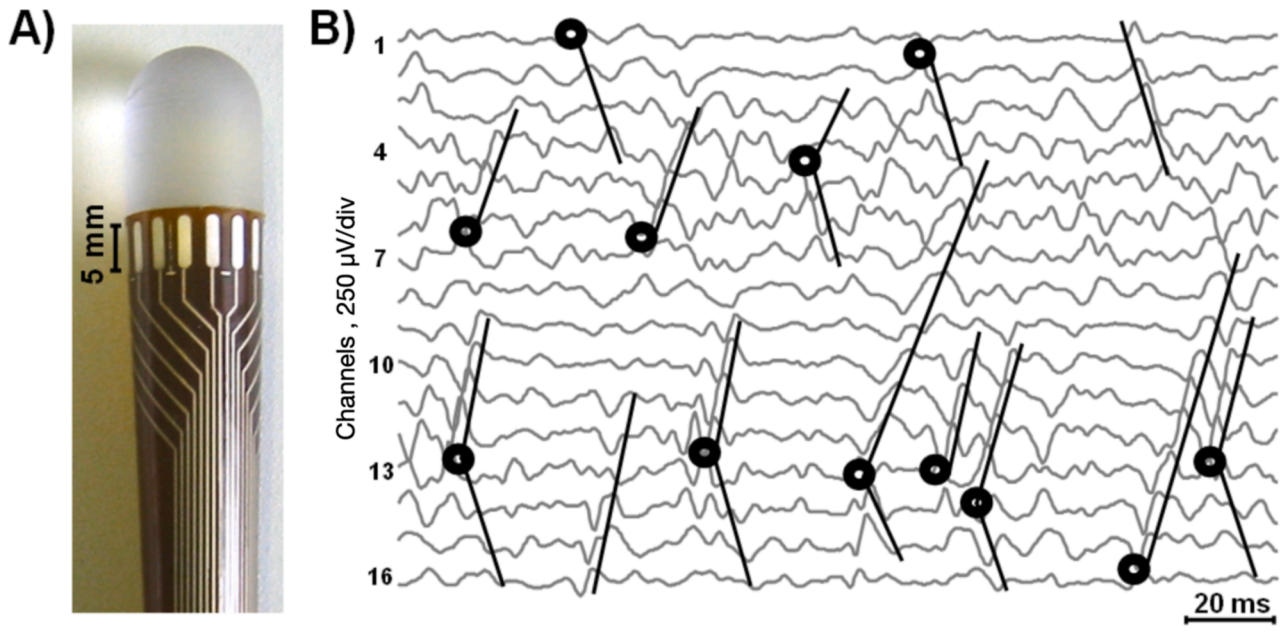

Fig. 1. Rectal electromyographic probe for single use diameter 14 mm with 16 electrodes. The electrodes are signed with numbers: 1,4,7,10,13,16. B) Example of multichannel superficial anal electromyographic recording of the external anal sphincter. Reproduced from Cescon et al., 2006 with permission from Elsevier. ©2024 Elsevier.

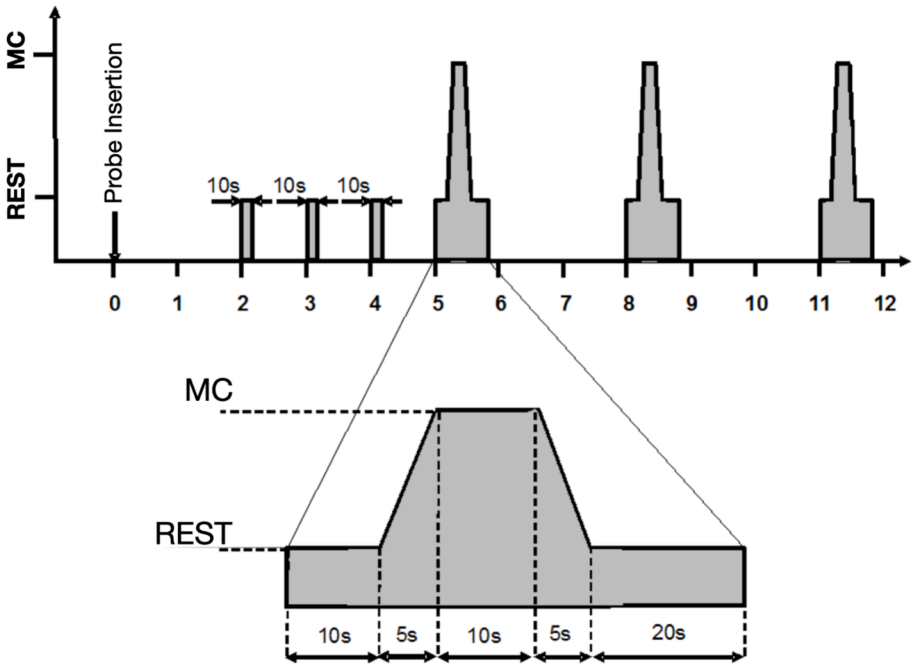

Fig. 2. Schematic representation of the EMG signal recording process. (MC: Maximal Contraction).

highlighting changes in the innervation zones and functional outcomes post-delivery.

3. Results

The patient's clinical and relevant labor characteristics are listed in Table 1. The electromyographic analysis of the anal sphincter before and after the delivery are illustrated in Figs. 3 and 4. The results of the examinations performed on all four patients are summarized in Table 2.

Case 1 (Cesarean Section).

The 34-year-old participant patient showed no change in the innervation zones or EMG amplitude post-delivery, indicating no impact on the EAS from the cesarean section. The average EMG amplitude values before and after delivery demonstrated stability across the measured conditions (rest and maximal contraction). No injuries were noted at the endoanal ultrasound (Fig. 5).

Case 2 (Episiotomy with EAS Injury).

The second case concerns a 35-year-old woman with an episiotomy and an identified injury to the UR quadrat of the EAS (Fig. 6). This case showed a reduction in the number of innervation zones in the UR quadrant and a notable decrease in EMG amplitude post-delivery, especially during maximal contraction. It is noteworthy that the

Table 1
Patients' clinical and relevant labor characteristics.

	CASE 1	CASE 2	CASE 3	CASE 4
AGE	34	35	32	31
HEIGHT	165 cm	171 cm	165 cm	169 cm
WEIGHT	71 kg	83 kg	76 kg	80 kg
DELIVERY	Cesarean section	Vaginal delivery	Vaginal delivery	Vaginal delivery
G.A.	41 weeks	40 weeks	41 weeks	37 weeks
LABOR DURATION	1 h	8 h	11 h	16 h
LABOR STIMULATION	Oxytocin	Oxytocin	None	Oxytocin
EPISIOTOMY		3 cm at a 50 degree angle	3 cm at a 40 degree angle	4 cm at a 40 degree angle
FUNDAL PRESSURE		Yes	No	Yes
INFANT WEIGHT	3785 g	3680 g	3470 g	2890 g
INFANT HEAD CIRCUMFERENCE	33.5 cm	34.0 cm	35.0 cm	35.0 cm

reduction in the number of innervation zones in the UR quadrant post-delivery aligns with the findings in Case 4, suggesting episiotomy's influence extends beyond physical injury to affect neural distribution within the EAS. The Wexner score was 2 and it was solely related to the inability to retain gasses.

Case 3 (Episiotomy with EAS Injury).

This 32-year-old woman's case also involved an episiotomy with EAS injury (Fig. 7). Despite an injury to the EAS, there was no change in the number of innervation zones in the UR quadrant, with the Wexner score remaining at 0, indicating no FI. The EMG amplitudes, hoverer, varied before and after delivery.

Case 4 (Episiotomy without EAS Injury).

This case involved a 31-year-old woman who underwent a vaginal delivery with episiotomy at 37 weeks. Before delivery, the EMG amplitude was high during maximal contraction and lower at rest, indicating that the patient had good anal sphincter muscle tone and strength. However, a notable reduction in the number of innervation zones in the UR quadrant was observed after delivery, alongside a decrease in EMG amplitude during rest and an increase during maximal contraction. This suggests that the patient's anal sphincter muscles had been weakened by the delivery process. The participant experienced mild FI, indicated by a Wexner score of 3. At endoanal ultrasound there were no injuries in the EAS (Fig. 8).

3.1. Main findings

Comparing these cases reveals episiotomy's potential to affect the EAS's neural and functional integrity even without direct muscle injury. Case 4 offers compelling evidence of episiotomy's specific impact on the innervation zones of the EAS, distinguished from the baseline established by the cesarean section case.

4. Discussion

This study builds upon prior research demonstrating the potential of intra-anal sEMG for detecting IZs of the EAS motor units. While previous studies, including the TASI-2 multicenter study, have demonstrated the efficacy of sEMG in assessing the innervation patterns of the pelvic floor muscles, these investigations had notable limitations (Cescon et al., 2014b; Dias et al., 2018; Začesta et al., 2021). Our study addresses two key limitations found in earlier research: the lack of an objective tool to confirm muscle injury and the absence of a reliable method to assess the clinical implications of IZ reduction.

First, we incorporated endoanal ultrasound into the methodology, which provided us with the ability to directly visualize muscle integrity. This is particularly relevant in cases where trauma to the EAS might not be evident through visual inspection alone, such as if the vaginal mucosa remains intact (Sultan et al., 1993; Walsh and Grivell, 2015). By confirming or excluding muscle damage through ultrasound, we offer a more comprehensive assessment of the episiotomy's impact on both the structural and neural integrity of the sphincter. This aspect was missing in the TASI-2 study, which did not utilize ultrasound to detect potential EAS damage that could lead to functional impairments.

Second, although innervation zone asymmetry of the EAS has already been proven as a risk factor for fecal incontinence, and this asymmetry could be further impacted by mediolateral episiotomy, no clinical tool was previously used to quantify the consequences of these neural changes (Dias et al., 2018; Nowakowski et al., 2017; Začesta

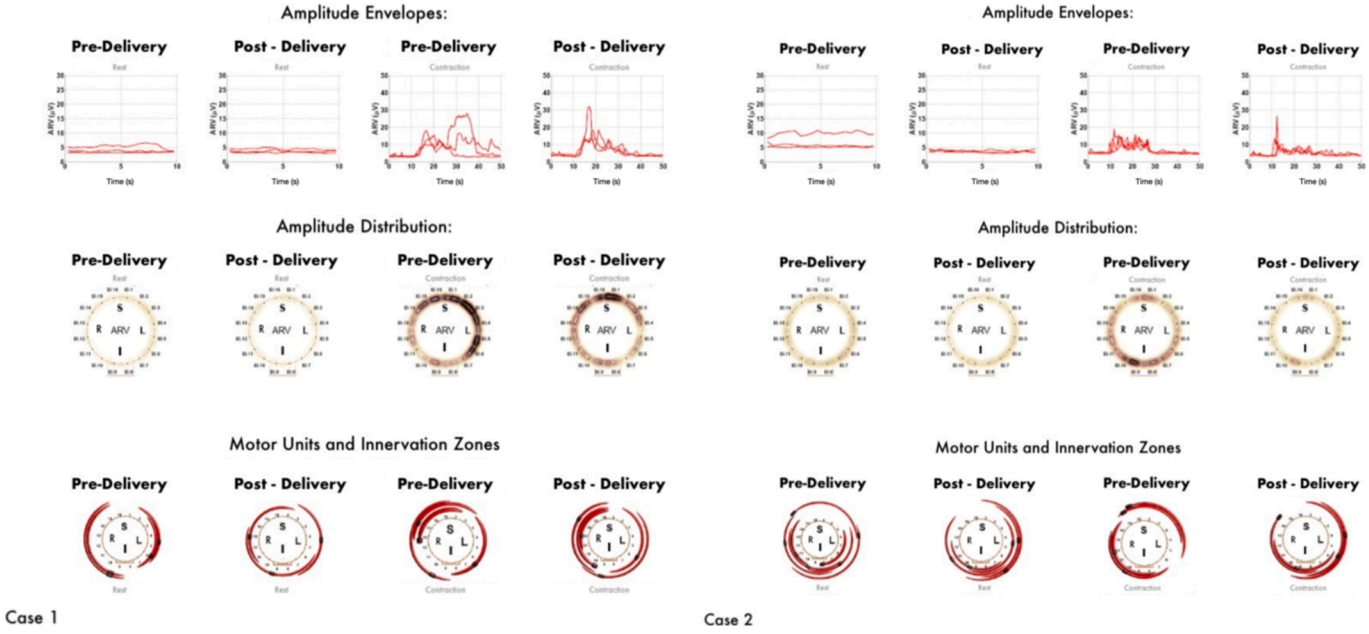

Fig. 3. Electromyographic analysis of the anal sphincter before and after delivery of cases 1 and 2. The top row shows amplitude envelopes of average values over time; for resting and for maximal contraction of the anal sphincter before and after delivery. The middle row shows amplitude distributions. The bottom row shows motor units and innervation zones and their distribution during rest and maximal contraction before and after delivery.

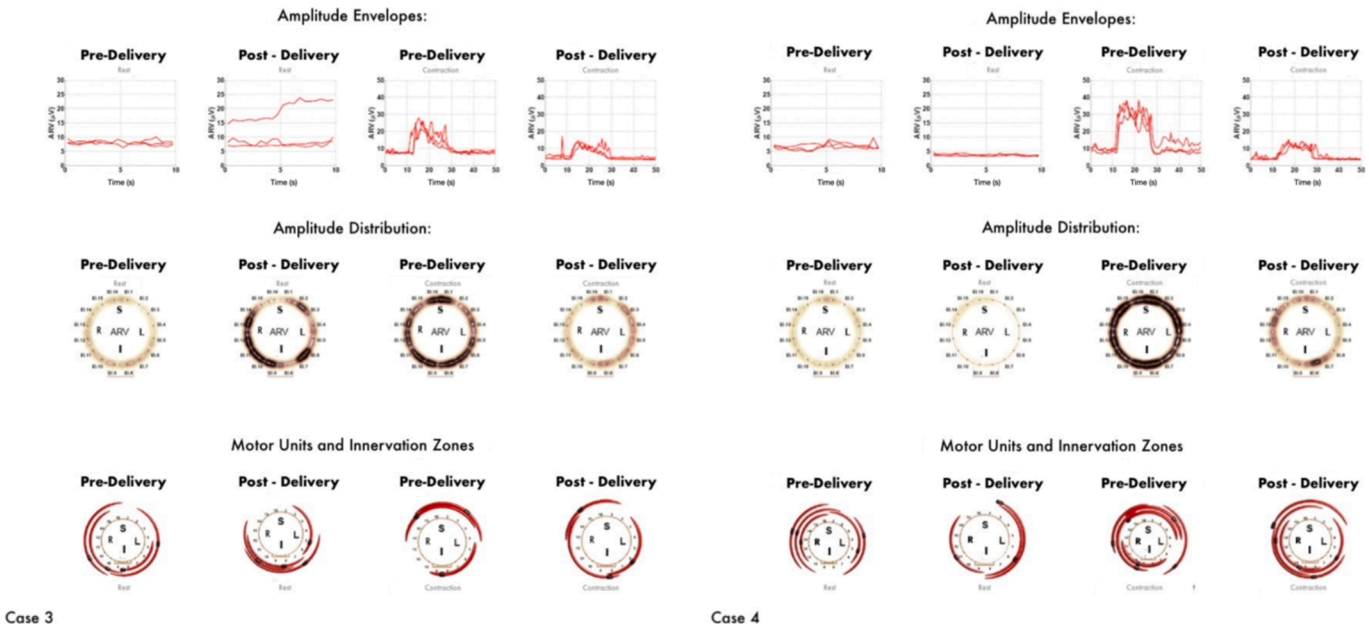

Fig. 4. Electromyographic analysis of the anal sphincter before and after delivery of cases 3 and 4. The top row shows amplitude envelopes of average values over time; for resting and for maximal contraction of the anal sphincter before and after delivery. The middle row shows amplitude distributions. The bottom row shows motor units and innervation zones and their distribution during rest and maximal contraction before and after delivery.

Table 2
Endoanal ultrasound findings, surface electromyography results, and clinical outcomes for all four cases at rest and during maximal contraction.

CASE	1	2	3	4
Episiotomy	N	Y	Y	Y
Injury at EndoUS	N	Y	Y	N
Innervation Zones – Rest, **Pre**	0, 2, 2, 0	1, 2, 3, 1	0, 1, 3, 0	1, 1, 1, 2
Innervation Zones – Rest, **Post**	1, 0, 1, 1	1, 2, 2, 0	0, 3, 1, 0	0, 1, 1, 1
Innervation Zones – Max, **Pre**	0, 1, 2, 1	0, 0, 2, 2	1, 1, 0, 1	1, 1, 3, 1
Innervation Zones – Max, **Post**	0, 1, 2, 2	1, 1, 1, 1	0, 2, 0, 1	1, 2, 2, 0
Avg. EMG Amplitude (μV) – Rest, **Pre**	4	7	8	7
Avg. EMG Amplitude(μV) – Rest, **Post**	4	4	12	4
Avg. EMG Amplitude(μV) – Max, **Pre**	11	10	18	30
Avg. EMG Amplitude (μV) – Max, **Post**	13	6	10	11
Wexner Score	0	2	0	3

Numbers in rows 3 to 6 refer to the number of innervation zones (IZs) detected in each quadrant of the EAS in the following order: Upper Left (UL), Lower Left (LL), Lower Right (LR), and Upper Right (UR). Numbers in rows 7 to 10 refer to EMG amplitudes reported in microvolts (μV).

et al., 2018). In this study, we addressed this limitation by incorporating the Wexner score, a well-established metric for evaluating fecal incontinence (Wexner, 2021). By correlating the reduction in IZs with Wexner scores, we were able to assess not only the anatomical but also the functional implications of IZ alterations. This approach bridges the gap between neurophysiological findings and patient-reported outcomes, providing stronger evidence of the clinical impact of neural changes in the EAS following episiotomy. Interestingly, our study found no significant increase in the global number of MU innervation zones between rest and maximal contraction, both pre- and post-delivery. This observation might reflect unique recruitment patterns of the EAS, which differ from skeletal muscles typically exhibiting increased IZ recruitment during maximal effort. Alternatively, it may highlight limitations of sEMG in detecting subtle recruitment changes or smaller innervation zones. These findings underscore the need for further research to better understand the neuromuscular control mechanisms of the EAS and how childbirth-related interventions may alter these dynamics.

4.1. *Barriers to clinical adoption*

Despite the potential benefits demonstrated in this and previous studies, the clinical adoption of sEMG for the assessment of EAS innervation remains limited. This can be attributed to several factors, which can be broadly categorized as cultural, educational, and technical barriers (Martin and Acosta-Sojo, 2021; Medved et al., 2020; Merletti et al., 2021).

From a cultural perspective, many healthcare providers perceive sEMG as a research tool with limited practical utility (Jette, 2017). The prevailing assumption is that significant sphincter injury is primarily associated with direct muscular trauma, which can be easily identified during delivery or through routine postpartum examination. As a result, the value of detecting neural alterations, particularly in the absence of visible muscle damage, is often underestimated which leads to many anal sphincter injuries remaining unrecognized at the time of delivery (Berg and Sahlin, 2020; Taithongchai et al., 2020). However, similarly to what we showed in our study with the Wexner score, other studies have highlighted the clinical implications of altered sEMG signals post-episiotomy. Min et al., in their large prospective studies, demonstrated that lower sEMG values during fast contractions in women who had undergone episiotomies were associated with urinary incontinence symptoms and a lower quality of life, both assessed using standardized questionnaires (Min et al., 2023). These findings underscore the importance of linking sEMG findings to patient-reported outcomes in clinical settings.

Educational barriers also contribute to the slow adoption of sEMG. There is insufficient training on the clinical applications of sEMG in medical curricula, particularly in obstetrics and gynecology, as well as in physiotherapy and rehabilitation fields (Manca et al., 2020). Many clinicians and healthcare professionals are unfamiliar with how to interpret sEMG data, limiting the technology's application in clinical practice. The complexity of interpreting sEMG signals, which requires a deep understanding of neuromuscular physiology and biomechanics,

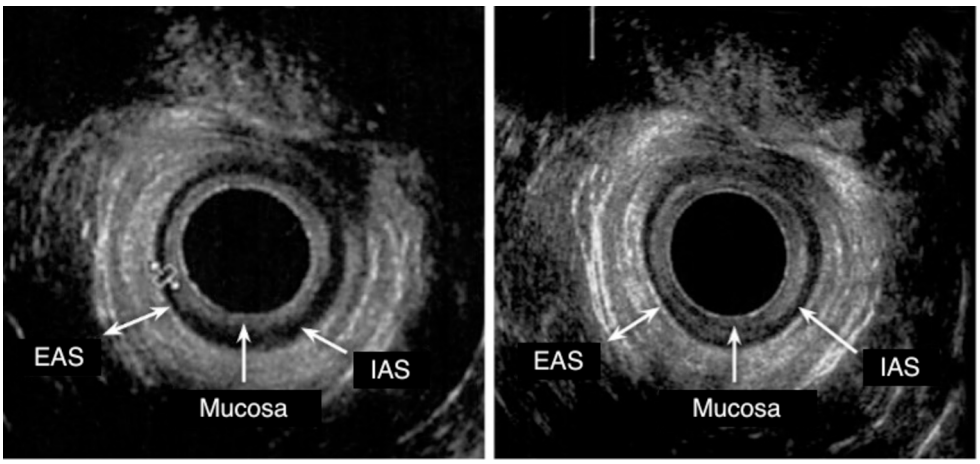

Fig. 5. Endoanal ultrasound before and after caesarian section (Mucosa: Anal Mucosa; EAS: external anal sphincter; IAS: internal anal sphincter).

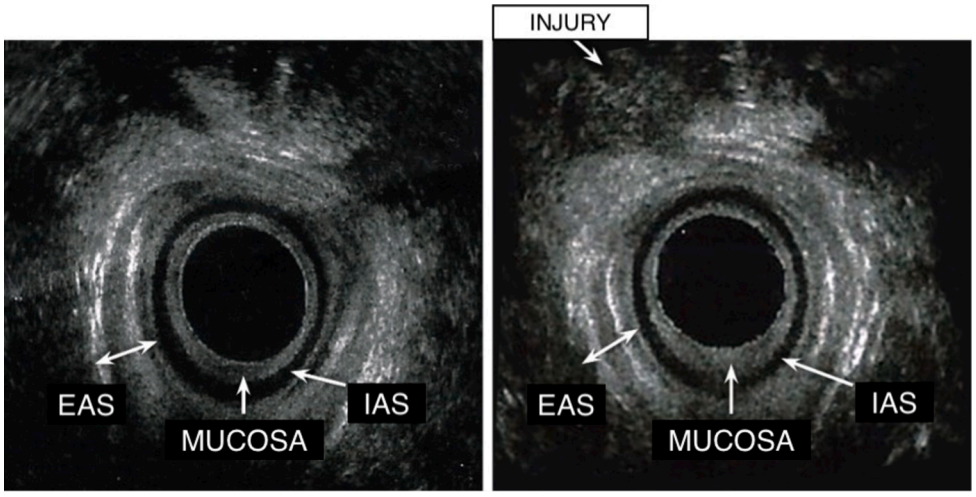

Fig. 6. Endoanal ultrasound before (left image) and after episiotomy, done at a 40–50 degree angle to the midline (right image) – injury to anal sphincter visible (Injury: injury of the external anal sphincter; Mucosa: Anal Mucosa; EAS: external anal sphincter; IAS: internal anal sphincter).

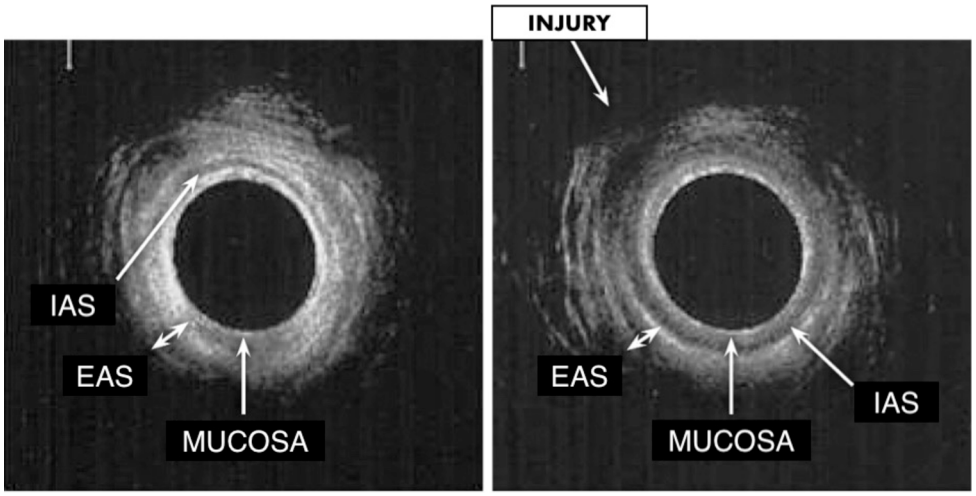

Fig. 7. Endoanal ultrasound before (left image) and after episiotomy, done at a 40–50-degree angle to the midline (right image) – injury to anal sphincter visible (Injury: injury of external anal sphincter; Mucosa: anal mucosa; EAS: external anal sphincter; IAS: internal anal sphincter).

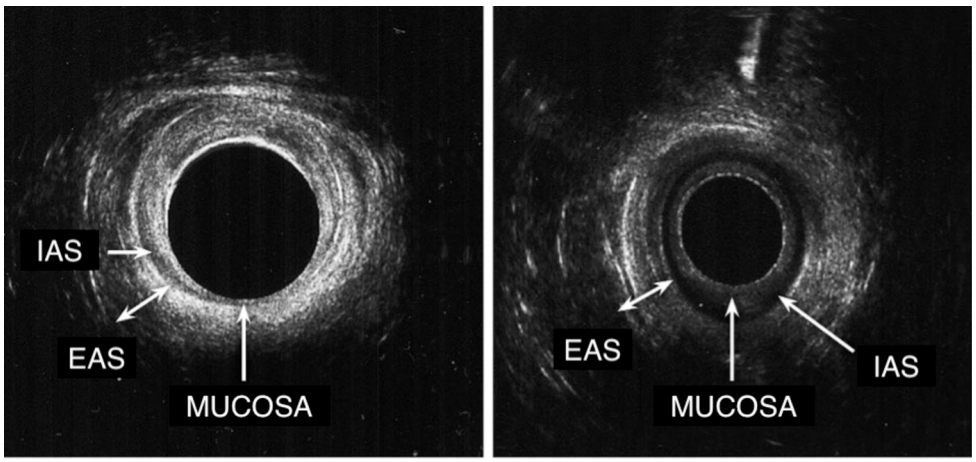

Fig. 8. Endoanal ultrasound before (left image) and after episiotomy, done at a 40–50-degree angle to the midline (right image) – no injuries to anal sphincter visible (Mucosa: Anal Mucosa; EAS: external anal sphincter; IAS: internal anal sphincter).

has further restricted its use. The lack of teaching on sEMG methodology in academic courses for obstetricians and midwives, even a decade after its introduction through European Union projects, raises significant concerns. While delays in adopting new methodologies are not uncommon in medical education, a ten-year gap is notable. Several factors could contribute to this delay, including cultural resistance to change, slow adaptation of emerging technologies, limited research and evidence and insufficient training resources. Advocacy policies can play a crucial role in spreading knowledge about surface electromyography. Societies such as the International Society of Electrophysiology and Kinesiology and the European Recommendations for Surface Electromyography could offer webinars and online courses on sEMG to make education more accessible to a wider audience.

Furthermore, advanced computational methods, such as automatic signal decomposition, may help overcome some of the educational barriers associated with sEMG interpretation. The automatic decomposition of motor unit potentials, as demonstrated in our study, simplifies data interpretation and enhances the accessibility of sEMG for clinicians who may not have advanced training in electromyography. While this is not Artificial Intelligence (AI), future integration of AI into sEMG systems could further enhance the process by enabling real-time analysis, improving accuracy, and potentially automating the identification of IZs. In the future, AI-driven sEMG systems could make this technology more accessible to less specialized healthcare professionals, ultimately supporting its wider adoption.

4.2. New indications and Future Directions

While this case series is limited by its small sample size and observational nature, it highlights the importance of further investigating the role of sEMG in guiding episiotomy decisions and assessing the neural and structural integrity of the EAS after childbirth. Specifically, this study suggests that even in the absence of visible muscular injury, episiotomy can affect the innervation zones of the EAS, contributing to pelvic floor dysfunction. This opens up new possibilities for utilizing sEMG in pre- and postpartum evaluations, particularly in assessing women who experience symptoms of fecal or urinary incontinence despite no apparent muscle damage.

Future research should also focus on exploring the dynamics of re-innervation following obstetric interventions. Investigating how innervation patterns recover after episiotomy, and how these patterns differ in women undergoing anal sphincter reconstruction, could provide valuable insights into the healing process and functional outcomes. Additionally, the correlation between vascular injury during childbirth and a diminished number of innervation zones deserves closer examination. Understanding the interaction between vascular and neural impairments may open new avenues for therapeutic interventions aimed at improving recovery and long-term pelvic health.

In conclusion, while sEMG is not yet widely integrated into routine clinical practice, it holds great promise as an additional tool for assessing the innervation of the anal sphincter, particularly in patients with sphincter injury or undergoing reconstruction. Although previous projects like TASI-2 have not fully translated into everyday use, the potential for sEMG in guiding interventions such as episiotomy and sphincter repair remains strong. Future research should focus on the dynamics of re-innervation after childbirth and reconstruction, and on understanding how vascular injuries correlate with reduced innervation zones. This evolving area of study could pave the way for more personalized, evidence-based approaches in pelvic floor care.

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CRediT authorship contribution statement

Kristina Drusany Starič: Writing – review & editing, Supervision, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gregor Norčič:** Writing – review & editing, Conceptualization. **Giorgia Campo:** Writing – review & editing, Methodology. **Rosario Emanuele Carlo Distefano:** Writing – original draft, Visualization, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Fig. 1b is reproduced with permission from Elsevier, originally published in Cescon et al. ©2024.

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