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Impact of selective surgical pelvic autonomic nerve damage on the evoked neuromonitoring signal of the internal anal sphincter

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Abstract

Introduction: A novel intraoperative neuromonitoring (IONM) method based on electric stimulation of pelvic autonomic nerves under electromyography of the internal anal sphincter (IAS) has been recently introduced to rectal cancer surgery. The aim of this experimental study was to investigate the impact of selective surgical pelvic autonomic nerve damaging on the evoked IONM signal of the IAS.
Methods: For this purpose 12 pigs underwent low anterior rectal resection. The pelvic splanchnic nerves were identified by means of electric stimulation under continuous electromyography of the IAS. For standardized neurostimulation, currents of 3 mA, frequency of 30 Hz and monophasic rectangular pulses with pulse duration of 200 µs were chosen. Surgical autonomic nerve damaging was performed on both pelvic sides while recording the evoked IONM signal of the IAS. Nerve damaging was carried out proximal to the stimulation point at the level of the pelvic splanchnic nerves and then distally at the level of the inferior hypogastric plexus. Scissors, monopolar diathermy, ultracision and waterjet were used for nerve damaging, each in 3 animals.
Results: Selective instrumental nerve damaging during neurostimulation resulted in a dissection specific superimposed artefact followed by a change in the evoked electromyographic amplitude, which could be observed online on the monitor of the IONM device. Comparison of the recorded IONM signals before and after proximal nerve damaging demonstrated a significant decrease in the evoked amplitude level (median 2.8 µV (interquartile range (IQR) 1.6; 5.7) vs. median 1.4 µV (IQR 0.6; 2.9), (p=0.026)). Nerve damaging performed distally to the stimulation point resulted in absence of evoked IONM signals.
Conclusion: The present study provided first differentiated insights into the dynamic IONM signal behaviour in response to selective pelvic autonomic nerve damaging. Further studies with neurophysiological and surgical IONM signal analysis are mandatory to reach a more accurate IONM resulting in effective nerve sparing pelvic surgery.

1 Introduction

Intraoperative neuromonitoring (IONM) in pelvic surgery has been developed to identify and preserve autonomic nerves, which are at risk to be damaged during the surgical procedure. The consequence of a substantial pelvic autonomic nerve damage is tremendous as it impairs patients´ quality of life by resulting in high rates of urinary, sexual and anorectal dysfunction. Most nerve damages were unexpected and unrecognized as these nerves are very complex in their distribution forming a fine neural network. Thus, the exact moment of a clinical relevant nerve damage and its causes during the operation can only be speculated. Insights into the complex functional pelvic neuroanatomy were provided by a novel IONM method based on electric stimulation of pelvic autonomic nerves under electromyography of the internal anal sphincter (IAS), which was recently introduced to rectal cancer surgery [1].

Based on this method, the focus of the present experimental pioneering study was the first in-depth investigation into the impact of selective surgical nerve damage on the evoked IONM signal of the IAS.

2 Methods

2.1 Animals and surgery

Twelve male pigs weighing in median 29 kg underwent nerve-sparing low anterior rectal resection by a colorectal surgeon. General anesthesia was performed with thiopental sodium (Trapanal®, 2.5 g/100 ml i.v.) 12-15 ml/h and piritramid (Dipidolor®, 45 mg/ 45 ml i.v.) 8-10 ml/h. Vital parameters were monitored continuously by electrocardiogram, measurements of arterial blood pressure, body core temperature, oximetry, end-tidal CO_2 and airway pressures. At the end of the experiment the animal was sacri-

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ficed with an overdose of thiopental sodium and 40 ml KCl 7.45 % i.v.

Animal care and procedures were approved by the local authorities (Regional Board of Animal Welfare, Koblenz, Rhineland-Palatinate, Germany).

2.2 Experimental procedures

After rectal resection the pelvic splanchnic nerves were identified by means of electric stimulation under continuous electromyography of the IAS, which was carried out with an adapted IONM system. Electromyography was performed as previously described [2]. The recorded IONM signal of the IAS could be intraoperatively observed online on the monitor of the device. Neurostimulation was set to currents of 3 mA, frequency of 30 Hz and monophasic rectangular pulses with pulse duration of 200 μs. In order to exclude interferences from striated muscles, Pacuroniumbromid was intravenously induced (Pancuronium/-duplex Deltaselect®, 0.5 mg/ kg).

Surgical autonomic nerve damage was performed on both pelvic sides while recording the evoked IONM signal of the IAS. Damage was carried out proximal to the stimulation point at the level of the pelvic splanchnic nerves and then distally at the level of the inferior hypogastric plexus (**Fig. 1**). Scissors, monopolar diathermy, ultrasonically activated scalpel and waterjet were used for nerve damage, each in 3 animals. For monopolar diathermy (Electrosurgical Unit, Erbe Elektromedizin GmbH, Tübingen, Germany) the generator was set to coagulation mode. Ultrasonically activated scalpel (Ultracision, Harmonic Generator 300®, Ethicon Endo-Surgery, Norderstedt, Germany) was used with a cutting speed of level 3 at a frequency of 55.5 kHz. Waterjet (Erbejet 2®, Erbe Elektromedizin GmbH, Tübingen, Germany) was set to a pressure of 50 bar and continuous suction to 200 mbar as these settings were suggested by a previous study using waterjet for rectal cancer surgery [3].

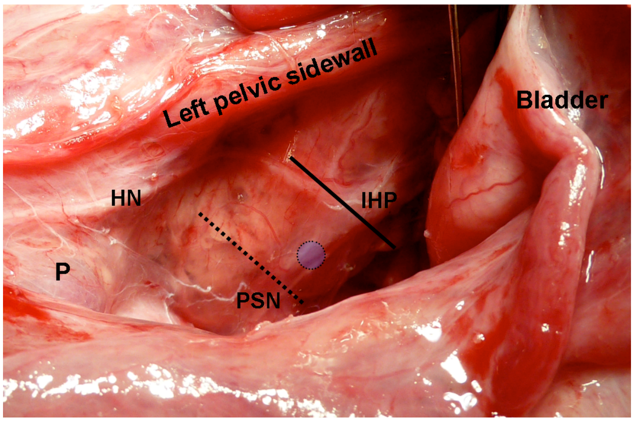

Fig. 1 Selective instrumental autonomic nerve damaging after low anterior rectal resection initially performed proximal (dashed line) to the stimulation point (circle) and then distally (solid line). P promontorium, HN hypogastric nerve, PSN pelvic splanchnic nerves, IHP inferior hypograstric plexus.

2.3 Data and statistical analysis

The recorded IONM signals of the IAS were postoperatively analyzed in MATLAB version 7.7.0.471 (The MathWorks, Inc., Natick, Massachusetts, USA) [2].

Statistical analysis was carried out with the Statistical Package for Social Sciences program (SPSS®) version 19.0 (SPSS Inc., Chicago, Illinois, USA). Comparison of the evoked IONM signals during the periods of selective surgical nerve damage was done using the Wilcoxon´s signed rank test. Comparison of the amplitude increases produced by the dissection specific superimposing artifacts during proximal and distal nerve damaging on both pelvic sides was performed with the Kruskal-Wallis test. Results were expressed as median and interquartile range.

3 Results and Discussion

Pelvic autonomic nerve damage performed with scissors, monopolar diathermy, ultracision and waterjet resulted in dissection specific artefacts, which could be observed online on the monitor of the IONM device (**Fig. 2**).

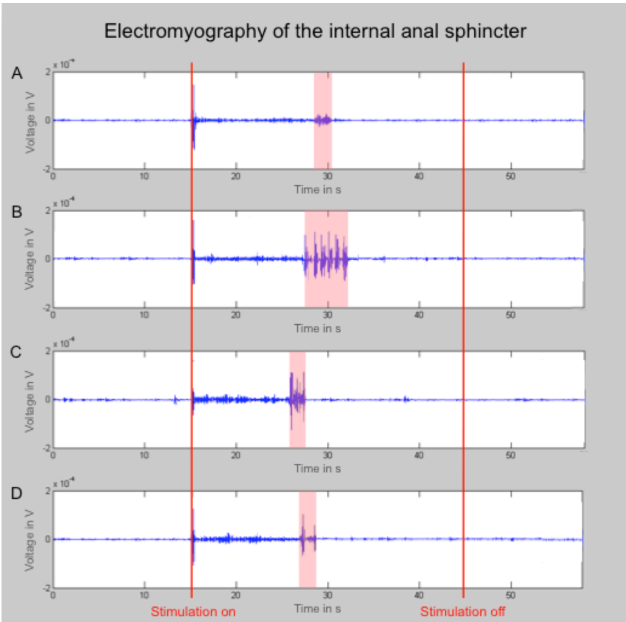

Fig. 2 Instrumental autonomic nerve damaging performed distally to the stimulation point while recording the evoked neuromonitoring signal of the internal anal sphincter. Nerve damaging (time period marked in red) was carried out using scissors (A), monopolar diathermy (B), ultracision (C) and waterjet (D).

The artefacts produced by each dissection technique superimposed the IONM signal of the IAS and thereby interfered with the electromyographic recordings. In these specific situations signal interpretation is difficult as the underlying IONM signal is disguised by the instrumental nerve damage. In the present investigations, IONM signal was more disturbed by artefacts during monopolar dia-

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thermy (**Fig. 3**). The reason for this is the diffuse electric current spread. During dissection currents run from the active electrode through the body returning to the generator via the neutral electrode and thereby interfere with the IONM method. In case of ultracision, the occurrence of less artefacts could be explained by the lower lateral spread and the less deep penetration of energy compared to electrosurgery [4]. Furthermore, artefacts could be the result of coupling of electrical field generated by the ultracision device. The occurrence of dissection artefacts, while severing the autonomic nerves with scissors, might be due to singular mechanical interferences at the recording electrode or nerve fireing induced by mechanical stress. However, lowest amplitude increases of superimposing artefacts where observed by waterjet. It is conceivable, that the volume flow and water uptake into the surrounding tissue with dispersion of the endoneurium or the lower electrical interference of the device might diminish the artefact amplitudes.

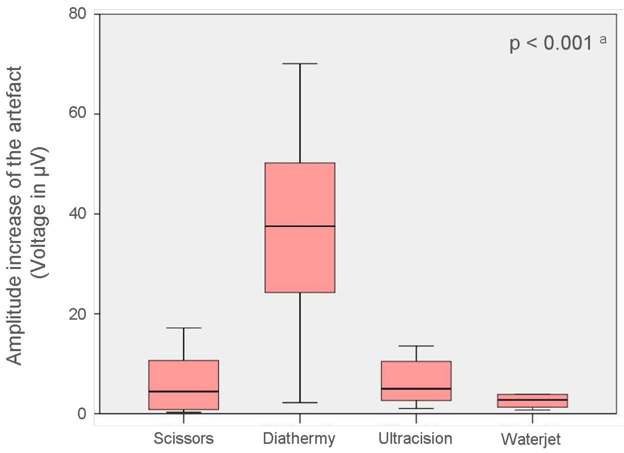

Fig. 3 Median amplitude increases of the superimposing artefacts during pelvic autonomic nerve damaging performed proximally and distally to the stimulation point on both pelvic sides with four different dissection techniques each in 3 animals (total median values; n = 48). [a] Kruskal-Wallis test

When developing methodological setups for a differentiated or continuous IONM in pelvic surgery, the effect of alternative dissection techniques on the continuous signal has to be taken into account. Therefore, further investigations of dissection techniques with regard to their nerve-sparing potential [5] and possible interferences with evoked IONM signals have to follow. Moreover, the question needs to be answered whether it is possible to further modify hard- and software of the IONM device in order to be less vulnerable to any artefacts.

An important finding of this brief study was the demonstration of significant differences between the recorded IONM signals before and after surgical damage of the pelvic splanchnic nerves proximal to the stimulation point (**Fig. 4**). Intraoperative observation of such signal changes might help to elucidate the character of autonomic nerve injury. A recent study provided new insights into the distribution of sympathetic and parasympathetic nerve fibres in the minor pelvis and showed that adrenergic and cholinergic fibres are coexistent in the pelvic splanchnic nerves, which makes neuroanatomy much more complex than previously thought [6]. The electric stimulation of such nerve branches may have a modulatory effect on the autonomic nervous system and might probably simultaneously influence afferent and efferent neural pathways. The observed lower evoked electromyographic amplitudes might be explained by the reduction or even elimination of excitatory or inhibitory neural effects.

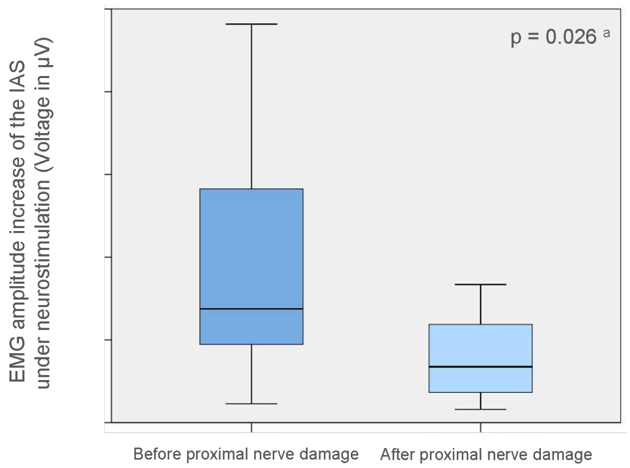

Fig. 4 Evoked electromyographic (EMG) amplitudes of the internal anal sphincter (IAS) before and after instrumental nerve damaging proximal to the stimulation point (total median values; n = 24 per group). [a] Wilcoxon´s signed rank test.

However, after surgical nerve damage distally to the stimulation point at the level of the inferior hypogastric plexus, no evoked IONM signals could be observed anymore. The extrinsic innervation of the IAS is mediated through the inferior rectal plexus originating from the inferior hypogastric plexus [7], which receives nerve supply from the hypogastric nerve and the pelvic splanchnic nerves. In accordance to the distribution of the autonomic nerve supply to the IAS the present results demonstrated that serious nerve damaging performed at the level of the inferior hypogastric plexus resulted in denervation of the IAS.

The study is limited to the relatively small number of animals and the four dissection techniques used for nerve damage. Further investigations should be performed with a larger population and techniques such as ligasure and bipolar scissors.

4 Conclusion

The evaluation of IONM signals during selective surgical pelvic autonomic nerve damage performed proximally and distally to the stimulation point, provided insights into the dynamic IONM signal behaviour and thereby instructive information for future investigations. This could enhance the ability to correctly interpret intraoperative signals and might be useful for identifying critical areas where pelvic autonomic nerves are at risk to be damaged during pelvic surgery. The understanding of such signal changes and superimposing artefacts during nerve damage with different dissection techniques may help to develop IONM systems with more signal stability and relative independence from external interferences.

4 Aknowledgements

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