

Deep neuromuscular paralysis during hip arthroscopic surgery: influence on perineal tissue pressures and hip joint width

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ABSTRACT

Pudendal nerve injuries are not an uncommon side effect of patient positioning on a traction table, and muscle relaxation has been suggested to mitigate this risk by reducing pressure on the perineum. A total of 40 patients scheduled for hip arthroscopic surgery under general anaesthesia were recruited. After induction of anaesthesia, pressures on the perineum were measured in 20 subjects by means of an ultra-thin pressure sensor mat wrapped around the perineal post. Perineal pressures were assessed after the induction of anaesthesia, after leg traction and after deep muscle relaxation. In 22 subjects, the hip joint width was measured radiographically at the same time points. Pressures on the perineum were high after traction (median maximum pressure 2540 g cm⁻²). Neuromuscular paralysis reduced perineal pressures only minimally, but significantly (−5 g cm⁻²; $P=0.007$). Traction increased hip joint width significantly [mean 66 (12)%; $P=0.001$] and muscle relaxation further increased joint width by a mean of 3.2 (0–20)% ($P=0.001$). Muscle relaxation was more beneficial for male patients (joint width increase 6.8% versus 2.8%; $P=0.04$), as well as patients in whom traction alone did not achieve sufficient joint width. Muscle relaxation reduced the perineal pressure during hip arthroscopic surgery by only a negligible amount. With regard to joint space, relaxation may be of highest benefit in male patients and/or patients in whom traction alone produces only a relatively small increase in joint width (trial registration: ANZCTR 12617000191392).

INTRODUCTION

Hip arthroscopic surgery frequently requires significant traction on the operated leg, and such force has been reported to increase the pressure on the patients' perineum via the perineal post of the operating table [1–6]. The resulting pressure on the pudendal nerve appears to result in a high number of short- to median-term neuropraxia with male and female sexual dysfunction as a serious consequence [1, 7, 8]. In fact, complications of hip arthroscopic surgery are amongst the top 3 topics discussed in the top

30 publication about hip arthroscopic surgery with the highest impact between 1900 and 2018 [9]. Although the rate of pudendal nerve recovery tends to be high within the first year after surgery, some patients may be left with long-term sequelae [1]. Muscle relaxation during general anaesthesia has been suggested to potentially reduce the pressure on the pudendal nerve as less leg traction may be required to overcome muscle tension [2]. However, this hypothesis has never been prospectively tested. Thus, it was the purpose of the current study to investigate the

effects of (deep) neuromuscular paralysis on the perineal pressure during hip arthroscopic surgery. Furthermore, we aimed to evaluate the effects of muscle relaxation on the hip joint width after the application of leg traction.

The hypothesis of the study was that muscle relaxation may have an impact on both perineal pressures and hip joint width.

METHODS

After approval of the institutional review board (27 April 2018) and trials registry registration, 40 otherwise healthy patients, aged 18–60 years and scheduled for hip arthroscopic surgery under general anaesthesia, were included in the study. The indication for hip surgery was known or suspected labral injury in all patients.

Patients with an incapacity to consent, a known allergy to one of the anaesthetic drugs (including muscle relaxant) used in the study, a history of neuropathy or any anatomical abnormality deemed to be a hindrance to implementation of the study protocol and patients receiving a femoral nerve block or neuraxial anaesthesia were excluded from participation.

The initial 20 patients were included in the first arm of the study, the investigation of the effect of muscle relaxation on perineal pressures. Thereafter, and after testing the feasibility of the second study arm (effect of muscle relaxation on the hip joint width) in two patients of the first part of the study, additional 20 patients were included.

Anaesthesia: After positioning on the operating table, all patients received a total intravenous anaesthetic with opioid/propofol. The depth of anaesthesia was monitored using state entropy or bispectral index electroencephalographic monitoring and maintained constant within the recommended range. The degree of muscle relaxation was recorded via quantitative neuromuscular monitoring (60 mA, 2 Hz, train-of-four pattern of ulnar nerve stimulation with acceleromyometric assessment of the movement of the adductor pollicis brevis muscle).

Investigating the effect of muscle relaxation on perineal pressure

All patients included in the first arm in the study were positioned on the operating table using the Smith-Nephew Advanced Supine Hip Positioning System with a 23-cm diameter padded single-use perineal post (Smith-Nephew, Andover, MA, USA).

Monitoring of perineal pressures: In the first 20 patients, an ultra-thin pressure sensor mat [Conformable TractArray System (thickness < 1 mm; 160 mm × 160 mm; spatial resolution 5 mm × 5 mm); PPS, Los Angeles, USA] was wrapped around the perineal post outside its

foam padding but protected from patient contact via a thin plastic and outer cotton liner. The pressure sensor was then connected via a T4500 high speed interface (PPS, Los Angeles, USA) to the USB2 port of a laptop computer (Chameleon 2012 pressure analysis software; PPS, Los Angeles, USA) and custom analysis software Pressure Mat 2.0 (Dept. of Medical Engineering, Royal Perth Hospital, Perth, Australia) and permitted high speed (real-time) monitoring of the perineal pressure.

For this first arm of the investigation, patients were placed with the perineum against the perineal post and the leg abducted to 45°. In male patients, the testicles were retracted superiorly. After anaesthesia induction but prior to muscle relaxation, traction was applied on the operated leg by adducting the leg to the neutral position and subsequently applying in-line traction to achieve sufficient joint width to allow arthroscopic access. After application of traction the resulting perineal pressures were recorded. Thereafter, the muscle relaxant rocuronium (0.6 mg kg⁻¹) was administered intravenously and, 2 min after administration and with confirmed deep neuromuscular block, perineal pressures were again recorded.

Investigating the effect of muscle relaxation on hip joint width

For the additional patients in this study arm a modified technique of traction was adopted. This was not a specific part of the study protocol but merely reflected a change in the surgeon's (T.S.L.) technique over the time of the entire study. The patient was placed supine with a 10-cm gap between the perineum and the padded post without Trendelenburg positioning. Alcoholic chlorhexidine skin prep was applied to the anterolateral thigh and the hip capsule vented with a needle from the hip portal entry kit (Stryker, Kalamazoo, USA). 50 cc of air was injected into the hip joint whilst in-line traction was applied simultaneously to the leg. This resulted in widening of the hip joint space whilst still maintaining a gap with no contact between the perineum and the padded post. Thereafter, patients received the muscle relaxant rocuronium (0.6 mg kg⁻¹) intravenously. Measurements were made with a metal ruler of known width placed at the level of the greater trochanter for calibration. Hip joint width was measured on image intensifier images pre-traction, post-traction and 2 min post-administration of rocuronium with the confirmation of deep neuromuscular block as above.

Statistics: As no related study exists, the study was designed as a pilot project with 20 patients in each arm (perineal pressure, hip joint width). All data were tested for normal distribution using the Kolmogorov–Smirnov test and data are displayed as mean (SD) or median (25%/

75% percentile), as appropriate. The Wilcoxon rank test was used to analyse the effects of traction and muscle relaxation, and ANOVA to investigate specific patient groups more likely to benefit from muscle relaxation.

RESULTS

Data of 40 patients [22 females, 18 males; body mass index (BMI) 27 (3.5); age 42 (9.3) years] were analysed.

The maximum pressure of the perineal post on the area of the pudendal nerve was 2540 (1915/3085) g cm^{-2} after the application of leg traction in anaesthetized but not paralyzed patients. In contrast, the median pressure was much lower: 277 (158/393) g cm^{-2} .

Deep muscle relaxation reduced this pressure only minimally, but with statistical significance by a median of 5 (1/12)% ($P=0.007$). A patient's BMI had no influence on the pressures on the pudendal nerve region.

The radiographically assessed joint width was 4.7 (3.9/5.0) mm at baseline, with a steep increase after the application of leg traction: 14.2 (13.5/16.3) mm ($P=0.001$). Deep muscle relaxation further increased joint space by 3.2 (0/6.5)% ($P=0.001$).

Patients with a baseline joint width below the median of 4.7 mm benefitted significantly more from leg traction than patients with a relatively large joint baseline width: increased width after traction 73 (4.8) versus 60 (14.8)% ($P=0.017$). Such difference was not found for the use of muscle relaxation.

Male versus female patients had less benefit (increase of hip joint width) from leg traction alone: 59.8 (16.8)% versus 70.3 (5.2)% ($P=0.041$), but more from additional muscle relaxation, with a mean increase of joint width of 6.8 (5.3)% versus 2.8 (3.0)% ($P=0.036$).

A further benefit for muscle relaxation was found for patients in whom traction only resulted in a below median increase in joint width. In these patients, muscle relaxation increased the joint space by a further 11.5 (7.4)% versus only 3.3 (3.3)% in patients who had above average joint space increase by traction alone.

DISCUSSION

To date, no study has investigated the effects of muscle relaxation on perineal pressures and on the hip joint width during hip arthroscopic surgery. Mallet *et al.* [2] suggested that muscle relaxation during operations on a traction table may have mitigating effects on the pressure of the pudendal post on the pudendal nerve, as they found a negative correlation between the dose of muscle relaxant given intraoperatively and the incidence of postoperative erectile dysfunction. However, at least as far as hip arthroscopic surgery is concerned, we did not find any clinically relevant

effect of muscle relaxation on the pressure measured at the region of the pudendal nerve. Hypothetically, and under conditions of a static traction force on the leg, muscle relaxation could be expected to result in significantly lower pressures by the perineal post. A potential explanation for the fact that we were unable to find such changes might be that we used a very large diameter (~ 23 cm) softly padded post. It has been previously reported that larger posts may result in significantly lower tissue pressures [10]. It is thus conceivable that using a standard (~ 9 cm diameter) post may have yielded different results. In our study, the thick foam padding of the Smith–Nephew post may also have absorbed some pressure changes, which might have been otherwise more detectable with the use of a less extensively padded post.

This hypothesis is supported by our finding of an increase in joint width after muscle relaxation, suggesting an overall decrease in muscle tension. It would have been interesting to explore this further by reducing the leg traction after muscle relaxation until a return to the pre-relaxation joint width—such manoeuvre would have very likely reduced the pressure by the perineal post. However, as we elected not to interfere with surgery or patient safety (with joint width facilitating arthroscopic surgery and thus considered a safety factor), we did choose not to intervene in this way.

Using the extensively padded post that we did, pressures recorded by us remained well below those reported by Brumback *et al.* [4] to cause pudendal nerve palsy.

Though we did not find any relevant influence of muscle relaxation on the pudendal nerve pressure, deep neuromuscular block had an influence on the width of the hip joint. Male patients as well as patients with a narrow joint width at baseline benefitted most from muscle relaxation. The need for either more traction force or less effect per given traction force found for male patients in our study is in line with the results of Ellenrieder *et al.* [11] who also reported higher traction requirements in males. The same authors also described a small minimum joint width (in our study called 'baseline' joint width) as a factor predicting the need for higher distraction forces—our study confirms this. Interestingly, Ellenrieder *et al.* [11] did not find a difference in the traction force requirements in patients having a general versus spinal anaesthesia. As a dense spinal anaesthesia would inevitably result in significant muscle relaxation below the level of the block, it appears at least likely that this type of anaesthesia may have resulted in lower forces required for sufficient hip joint distraction. However, as neither details about the level of motor block resulting from spinal anaesthesia nor details about the general anaesthetic technique (including muscle

relaxants used) are provided, no conclusion can be drawn about this aspect of their investigation.

This study has limitations: first, only a relatively small number of participants were included and, due to the lack of similar experiments, no formal sample size estimate was undertaken. However, the study is, to the best of our knowledge, the first to investigate the matter of neuromuscular paralysis and its influence on hip arthroscopic surgery. Second, for the investigation of perineal pressures, we utilized a very specific, heavily padded perineal post and results obtained in this study may ultimately not be applicable for other styles of perineal posts or other traction techniques than those described by us. Though it appears likely that the results can be, to a degree, extrapolated for the use of other, similar methods, they are certainly not universally valid for the entire range of hip arthroscopic methods. Third, the method of patient positioning was changed after the completion of study part 1 (perineal pressures). Though both study arms may be regarded as independent studies, the change in traction technique limited the investigation of a larger cohort of patients regarding perineal pressures as the measurement technique was only feasible for the first 20 subjects. However, the fact that we did not observe any clinically relevant changes in perineal pressures with muscle relaxation in 20 patients makes it unlikely that the inclusion of further patients would have resulted in different findings.

Based on the results of our experiments, we conclude that in the presence of a large diameter well-padded perineal post, deep muscle relaxation appears of little influence on the post-mediated pressure on the pudendal nerve. However, muscle relaxation had a small, but significant impact on the width of the hip joint. This influence was pronounced in male patients and patients with a small minimum joint width at baseline. It appears that muscle relaxation may not be required for all patients undergoing hip arthroscopic surgery, provided a similar set-up as described by us is used. However, deep neuromuscular block may be of significance in more difficult cases where the observed increase in workable joint width may play a significant role in making hip arthroscopy feasible and safe.

AUTHOR CONTRIBUTIONS AND FUNDING

This study was funded by the investigators (time) and no third party had any influence on its planning, conduct and data analysis. All authors sufficiently contributed to the manuscript to warrant authorship.

PREVIOUS PRESENTATIONS OF RESULTS

The results of this study have been presented at the ISHA 2019 annual meeting of the Hip Preservation Society in Madrid.

CONFLICT OF INTEREST

The corresponding author has received speaker honoraria and travel grants from Merck & Co., the manufacturer of the muscle relaxant rocuronium (off patent) and its reversal agent sugammadex, both used in this study. However, no funding or any other help was received in relation to this manuscript. All other authors declare no conflict of interest.

DATA SHARING

Data can be obtained on reasonable request from the corresponding author at his sole discretion. Data are available in SPSS file format only.

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