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Evaluation of surgical conditions during laparoscopic surgery in patients with moderate *vs* deep neuromuscular block

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Editor's key points

- Surgical conditions may be affected by the depth of neuromuscular block.
- This small study assessed conditions rated on a five-point scale by a single surgeon during retroperitoneal laparoscopic procedures.
- Surgical conditions were rated significantly better under deep neuromuscular block.
- The rating of surgical conditions on video analysis differed markedly between anaesthetists and the surgeon.

Background. The routine use of neuromuscular blocking agents reduces the occurrence of unacceptable surgical conditions. In some surgeries, such as retroperitoneal laparoscopies, deep neuromuscular block (NMB) may further improve surgical conditions compared with moderate NMB. In this study, the effect of deep NMB on surgical conditions was assessed.

Methods. Twenty-four patients undergoing elective laparoscopic surgery for prostatectomy or nephrectomy were randomized to receive moderate NMB (train-of-four 1–2) using the combination of atracurium/mivacurium, or deep NMB (post-tetanic count 1–2) using high-dose rocuronium. After surgery, NMB was antagonized with neostigmine (moderate NMB), or sugammadex (deep NMB). During all surgeries, one surgeon scored the quality of surgical conditions using a five-point surgical rating scale (SRS) ranging from 1 (extremely poor conditions) to 5 (optimal conditions). Video images were obtained and 12 anaesthetists rated a random selection of images.

Results. Mean (standard deviation) SRS was 4.0 (0.4) during moderate and 4.7 (0.4) during deep NMB ($P<0.001$). Moderate block resulted in 18% of scores at the low end of the scale (Scores 1–3); deep block resulted in 99% of scores at the high end of the scale (Scores 4 and 5). Cardiorespiratory conditions were similar during and after surgery in both groups. Between anaesthetists and surgeon, there was poor agreement between scores of individual images (average κ statistic 0.05).

Conclusions. Application of the five-point SRS showed that deep NMB results in an improved quality of surgical conditions compared with moderate block in retroperitoneal laparoscopies, without compromise to the patients' peri- and postoperative cardiorespiratory conditions.

Trial registration. The study was registered at clinicaltrials.gov under number NCT01361149.

Keywords: laparoscopy; nephrectomy; neuromuscular block; prostatectomy; rocuronium; sugammadex; urological surgical procedures

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Administration of muscle relaxation is essential in a variety of procedures as it causes an improvement of surgical conditions. For example, King and colleagues[1] demonstrated that the routine use of neuromuscular blocking agents reduced the frequency of unacceptable surgical conditions in radical prostatectomies. Improvement of surgical conditions may be even more important when the surgeon has to work in a narrow space surrounded by muscles such as in the case of retroperitoneal laparoscopic surgery. It may be argued that in retroperitoneal laparoscopic surgery, a deep neuromuscular block (NMB), with train-of-four (TOF) values of 0 and a post-tetanic count (PTC) of 1–2, would further improve working conditions. However, the use of deep NMB may come with complications including long-reversal times, incomplete recovery of neuromuscular function compromising respiratory, and upper airway function, or the return of NMB after a period of seemingly normal neuromuscular function (recurarization).[1–3]

The development of sugammadex enables rapid reversal of deep NMB. Sugammadex is a modified γ-cyclodextrin, especially created to bind the free plasma molecules of the neuromuscular blocking agent rocuronium to which it has high affinity.[4] Recent studies demonstrate that sugammadex produces rapid reversal of deep NMB after administration of high-dose rocuronium.[5] Theoretically, the combination of rocuronium and sugammadex makes it possible to achieve deep NMB and consequently further improve surgical conditions in retroperitoneal laparoscopic surgery without the fear for prolonged reversal times or incomplete recovery of

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neuromuscular function. However, the association between the depth of NMB and surgical conditions has not been evaluated as yet.

In the current study, we investigated the effect of a deep NMB (TOF 0, PTC 1–2) against a moderate block (TOF 1–2) on surgical conditions in patients undergoing retroperitoneal laparoscopic surgery for a prostatectomy or (partial) resection of a kidney. Surgical conditions were rated using a five-point surgical rating scale (SRS) by one dedicated surgeon with ample experience in these surgeries (R.F.B.). We hypothesize that deep NMB is associated with improved ratings by the surgeon. Secondary end points of our study included the assessment of the level of agreement between anaesthetists (the providers of the NMB agents and consequently responsible for a large part of the surgical conditions) and surgeon in terms of their rating of the surgical conditions. To that end, 30 s video images of the surgical field, obtained at the time of scoring by the surgeon, were rated by the anaesthetists.

Methods

The study (acronym BLISS trial) was carried out between November 2012 and February 2013 at the Leiden University Medical Centre (Leiden, The Netherlands) and was performed according to guidelines of Good Clinical Practice and Good Research Practice. Approval of the protocol was obtained from the institutional review board (Commissie Medische Ethiek, Leiden, The Netherlands). Patients scheduled to undergo an elective laparoscopic prostatectomy or nephrectomy (partial or total) were approached 2 weeks before surgery and received oral and written information about the study. All patients who were willing to participate gave written informed consent before enrolment. The study was registered at clinicaltrials.gov (NCT01361149); the protocol was published earlier online.[6] The design of the study was randomized (deep NMB against standard or moderate block) and blinded (the surgical team, the research team and the anaesthetists who scored the video were all blinded to the treatment); the attending anaesthetist was not blinded. Randomization was performed using a computer-generated randomization code. The code was presented to the attending anaesthetist who prepared the medication and took care of patient dosing during anaesthesia.

Patients enrolled in the study had prostate or renal disease and were all eligible for surgical resection by laparoscopic approach. All procedures were performed by one surgeon (R.F.B.). Excluded from participation were patients with ASA class >III, age <18 yr, inability to give informed consent, known or suspected neuromuscular disease, allergy to medication to be used during anaesthesia, a (family) history of malignant hyperthermia, renal insufficiency (serum creatinine >2 times normal, urine output <0.5 ml kg^{-1} h^{-1}, glomerular filtration rate <60 ml h^{-1}, or proteinuria), previous retroperitoneal surgery, and a body mass index of $\geq$35 kg m^{-2}.

Perioperative protocol

All patients received total i.v. anaesthesia with propofol and sufentanil. During the procedure, routine monitoring was applied [electrocardiography, arterial blood pressure, heart rate, electroencephalographic monitoring using the Philips bispectral index (BIS) module system (Philips, Eindhoven, The Netherlands)]. Propofol dosing was such that BIS values remained within the range of 40–50. Additionally, the cardiac output was measured non-invasively using an inflatable finger cuff attached to the Nexfin haemodynamic monitor (*bmeye*, Amsterdam, The Netherlands).

With respect to NMB the patients were randomly assigned to one of the two treatment groups:

Group 1: moderate NMB, in which the goal was to realize a moderate NMB (TOF 1–2 twitches). NMB was induced with a bolus dose of atracurium of 0.5 mg kg^{-1}, followed by a continuous infusion of mivacurium of 0.5 mg kg^{-1} h^{-1}. In the case of deviations from the target TOF values, the pump speed could be increased or decreased or a bolus dose could be given. This was left to the discretion of the attending anaesthetist. We used atracurium/mivacurium in Group 1 rather than low-dose rocuronium, as this combination is the current standard of care in our hospital. This approach enables us to qualify our current local practice against a new paradigm, which is deep NMB for the chosen surgical procedures.

Group 2: deep NMB, in which the goal was to realize a block of zero twitches in the TOF, but 1–2 twitches in the PTC. To that end, patients received a loading dose of rocuronium of 1.0 mg kg^{-1} followed by a continuous infusion of 0.6 mg kg^{-1} h^{-1}. In the case of deviations from the target TOF and PTC, the pump speed could be increased or decreased or a bolus dose could be given. This was left to the discretion of the attending anaesthetist.

In the case of poor or extremely poor surgical conditions (as scored by the surgeon, see below), mivacurium or rocuronium infusion rates were increased by 20% after the administration of a bolus dose of 15 mg.

At the end of surgery, all patients received a reversal agent: neostigmine after a moderate NMB (1–2 mg combined with 0.5–1 mg atropine) and sugammadex (4 mg kg^{-1}) after a deep NMB. Extubation occurred when the TOF ratio was >0.9.

Administration of all drugs was performed by the attending anaesthetists and not corresponded to the surgical team or the anaesthesia research team.

Monitoring

Neuromuscular function using an acceleromyograph was measured at the wrist (TOF-watch-SX, MSD BV, Oss, The Netherlands). The TOF-watch generates an electrical stimulus to the ulnar nerve and measures contractions of the adductor pollicis muscle (causing adduction of the thumb) through a sensor attached to the tip of the thumb. The thumb was placed in a flexible adaptor that applied a constant preload to the thumb. Before administration of any NMB agent, the device was calibrated according the specifications of the manufacturer. To that end, before administration of any neuromuscular blocking agent, but after induction of general anaesthesia, the following procedures were conducted to standardize the neuromuscular monitoring: (i) application of a tetanic ulnar nerve stimulation (50 Hz for 5 s); (ii) calibration of the TOF watch; and (iii) performing a series of TOF measurements ensuring that the TOF ratio differs by $<$5% between measurements. If the TOF ratio differed by $>$5% the TOF watch was recalibrated. The TOF ratio was normalized to the values obtained during the calibration procedure. After these steps, the neuromuscular blocking agent was administered according to protocol.

The number of thumb twitches upon electrical stimulation of the ulnar nerve was measured and recorded. At 15 min intervals, the TOF was measured and in the case of TOF=0, this was followed by the PTC. In our study, a TOF of 1–2 reflects a standard block and a PTC of 1–2 reflects a deep NMB. Finally, when four twitches were present in the TOF, the ratio of the fourth to the first twitch was determined (the TOF ratio).

Surgical rating scale

During the laparoscopic procedure, the surgeon scored the surgical working conditions at 15 min intervals according to a five-point ordinal scale ranging from 1 (extremely poor conditions) to 5 (optimal conditions) (Table 1). Extremely poor (Score 1) indicates that the surgeon is unable to work because of coughing or of the inability to obtain a visible field because of inadequate muscle relaxation; poor (Score 2) indicates that there is a visible field, but the surgeon is severely hampered by inadequate muscle relaxation with continuous muscle contractions, movements, or both; acceptable (Score 3) indicates that the there is a wide visible field but muscle contractions, movements, or both occur regularly; good (Score 4) indicates a wide working field with sporadic muscle contractions, movements, or both; excellent (Score 5) indicates a wide visible working field without any movement or contractions. In the case of a sudden deterioration of conditions additional measurements could be added. The feasibility of this method of scoring was investigated during five surgical procedures not included in the study.

Table 1 The surgical rating score

1	*Extremely poor conditions*: the surgeon is unable to work because of coughing or because of the inability to obtain a visible laparoscopic field because of inadequate muscle relaxation. Additional neuromuscular blocking agents must be given
2	*Poor conditions*: there is a visible laparoscopic field, but the surgeon is severely hampered by inadequate muscle relaxation with continuous muscle contractions, movements, or both with the hazard of tissue damage. Additional neuromuscular blocking agents must be given
3	*Acceptable conditions*: there is a wide visible laparoscopic field but muscle contractions, movements, or both occur regularly causing some interference with the surgeon's work. There is the need for additional neuromuscular blocking agents to prevent deterioration
4	*Good conditions*: there is a wide laparoscopic working field with sporadic muscle contractions, movements, or both. There is no immediate need for additional neuromuscular blocking agents unless there is the fear of deterioration
5	*Optimal conditions*: there is a wide visible laparoscopic working field without any movement or contractions. There is no need for additional neuromuscular blocking agents

Video images

Each time the surgeon rated the surgical conditions a 30 s video image was captured using a camera connected to the endoscopic probe placed in the retroperitoneal surgical space. The procedure was such that the images collected give a visual indication of the surgical condition at the time of scoring. A randomized subset of these images (n=10) was presented to 12 anaesthetists with ample experience in giving anaesthesia for urological laparoscopic procedures. They were asked to give a rating to the surgical condition using the same five-point scale as used by the surgeon. These anaesthesia experts were blinded to the level of NMB and goals of the study.

Data acquisition

The following clinical variables were collected on the case record form for further analysis: anaesthesia-related variables [drug dosages, BIS, time from reversal to optimal extubation conditions (TOF ratio $>$0.9)], haemodynamic variables (arterial blood pressure, heart rate, cardiac output, and cardiac index), ventilatory variables (tidal volume, breathing rate, and breathing pressure), surgical variables (SRS, intra-abdominal pressure, and duration of surgery), and post-anaesthesia care-related variables [time spent in the post-anaesthesia care unit (PACU), respiratory rate, oxygen saturation, pain score (on an 11-point numerical rating scale from 0, no pain, to 10, most severe pain imaginable), occurrence of nausea/vomiting and sedation (on a five-point scale ranging from 0, normal alertness to 5, not aroused by a painful stimulus)]. Recurrent observations were made at 15 min intervals both during anaesthesia and in the PACU.

Sample size and statistical analysis

The sample size was based on the expectation of the surgeon for the distribution of the surgical ratings between the two treatment conditions: rating during the moderate block=5 occurs in 10% of cases, 4 in 20%, 3 in 55% 2 in 10%, and 1 in 5%; rating during the deep block=5 in 70% of cases, 4 in 20%, 3 in 10%, 2 in 0%, and 1 in 0%. These anticipated frequencies result in an odds ratio of 21 for optimal conditions (SRS=5) *vs* non-optimal conditions (SRS$<$5). Ten thousand simulations were performed to obtain the power for a given sample size with moderate block as a fixed distribution and a simulated distribution of the deep block condition assuming proportionality of the odds ratio with an odds ratio of 21 and analysing the results with a proportional odds model using the score test. The power ranged from 82% at a sample size of 14 (7 in each group) to 97% (n=12 per group). A sample size of 24 was chosen to take into account any margin of uncertainty around the effect size.

The data analysis was based on the intent-to-treat approach. The primary end point of the study was the influence of the depth of the NMB on the SRS. For each patient, the final score was the average of all 15 min SRS values. The treatment effect on the final score was tested using a *t*-test (SigmaPlot version 12.5, Systat Software, Inc., San Jose, CA, USA). Secondary end points were (i) the assessment of the level of agreement between anaesthetists and surgeon in terms of their rating of the surgical conditions and (ii) the effects of level of NMB on haemodynamic variables during surgery, time to TOF>0.9, and relevant variables in the PACU (pain rating, sedation levels, and cardiorespiratory variables). All variables were averaged over time to get an indication of their mean value. Treatment effects were evaluated on the average data by *t*-test.

The scores of each of the 12 anaesthetists were compared with that of the surgeon's score using the κ statistic (also known as Cohen's κ) and population Bland–Altman analysis.[7–9] The κ statistic calculates the agreement between a pair of scores over and above what is expected from chance, where $\kappa=[P(A)-P(E)]/[1-P(E)]$, P(A) is the proportion of scores that agree and P(E) is the proportion of scores that would agree by chance.[7 8] Kappa values between 0 and 0.2 are indicative of poor to slight agreement, values between 0.2 and 0.4 indicate fair agreement, 0.4 and 0.6 moderate agreement, 0.6 and 0.8 substantial agreement, and 0.8 and 1 near complete to complete agreement.[10] Bland–Altman plots give the difference between paired measurements (scores) against the mean of the values, which results in values for bias and limits of agreement to describe how closely measurements from two sources are related.[9]

All values presented are mean (SD) unless otherwise stated. *P*-values <0.05 were considered significant.

Results

A total of 30 patients were screened. In four patients, one or more exclusion criteria were met. The others were randomized. Two patients withdrew consent before treatment; two others replaced them. See Figure 1 for the flow chart of the study. Patient characteristics are given in Table 2 showing that the two treatment groups were similar in physical characteristics, gender, types of surgery, and haemodynamic variables. Duration of surgery was similar between treatment groups and ranged from 80 to 240 min with average surgical times of 141 and 144 min for standard care and deep NMB, respectively (Table 3).

Anaesthesia

Depth of anaesthesia, as measured by the BIS of the electroencephalogram, was similar between treatment groups [moderate block 42 (5) *vs* deep block 44 (6)]. NMB in patients receiving a standard treatment was moderate with an average TOF of 2.2 (0.9) during surgery. Patients receiving a deep NMB had zero twitches in the TOF and 1.6 (1.5) twitches in the post-tetanic count. During surgery, the dosages of the anaesthetic (propofol) or analgesic (sufentanil), the intra-abdominal pressure and haemodynamic variables were similar between treatments (Table 3).

Rating of surgical conditions during laparoscopic surgery

The rating of the surgical field was significantly different between treatments with a mean rating of 4.0 (0.4) (range 3.5–4.5, median 3.9) during a moderate NMB with TOF 1–2 and 4.7 (0.4) (range 4.0–5.0, median 4.9) during a deep block with PTC 1–2 (*P*<0.001, Fig. 2). The distribution of all ratings taken during surgery is shown in Figure 3. From these data, the significant difference between the moderate (TOF 1–2) and deep (PTC 1–2) blocks is apparent from the fact that 18% of scorings during moderate block was in the SRS range of 1–3 (scores rated as less than good), while 99% of scoring

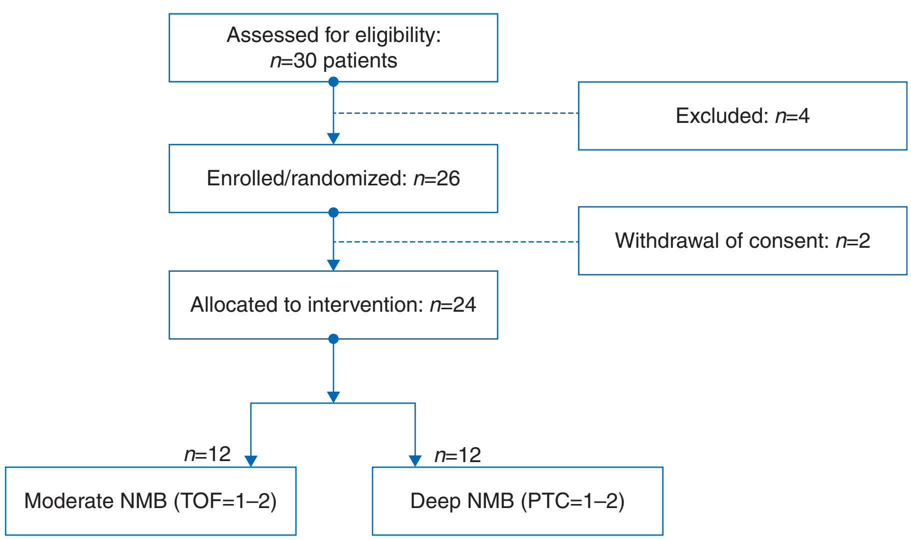

Fig 1 Study flow chart.

Table 2 Patient characteristics and screening measurements. All values are mean (SD) unless otherwise stated. BMI, body mass index; ABP, arterial blood pressure; HR, heart rate; CO, cardiac output; CI, cardiac index. Haemodynamic measurements were obtained before induction of anaesthesia

	Moderate NMB (*n*=12)	Deep NMB (*n*=12)
Prostate surgery (*n*)	7	7
Renal surgery (*n*)	5	5
Gender (M/F)	10/2	10/2
Age (median, range)	59 (28–74)	60 (24–70)
Weight (kg)	83 (14)	83 (10)
Height (cm)	180 (10)	180 (9)
BMI (kg m^{-2})	25.8 (3.2)	25.9 (3.9)
ABP systolic (kPa)	19.6 (2.1)	18.9 (1.5)
ABP systolic (mm Hg)	147 (16)	142 (11)
ABP diastolic (kPa)	11.2 (2.2)	11.5 (1.6)
ABP diastolic (mm Hg)	84 (15)	86 (12)
HR (min^{-1})	71 (12)	73 (15)
CO (litre min^{-1})	5.9 (1.6)	5.8 (2.4)
CI (litre min^{-1} m^{-2})	3.0 (0.8)	3.1 (1.0)

Table 3 Measurements during surgery. NMB, neuromuscular block; BIS, bispectral index; TOF, train-of-four; PTC, post-tetanic count; SRS, five-point surgical rating scale; AP, arterial pressure; HR, heart rate; CO, cardiac output; CI, cardiac index. Values are mean (SD). *P<0.001 *vs* moderate NMB

	Moderate NMB (TOF 1–2)	Deep NMB (PTC 1–2)
Duration of surgery (min) (range)	141 (50) (80–240)	144 (35) (90–195)
BIS	42 (5)	44 (6)
Propofol (g)	1.6 (0.8)	1.6 (0.4)
Sufentanil (μg)	73 (30)	78 (22)
Rocuronium (mg)		223 (81)
Atracurium (mg)	37 (10)	–
Mivacurium (mg)	41 (24)	–
TOF	2.2 (0.9)	0
PTC	–	1.6 (1.5)
SRS	4.0 (0.4)	4.7 (0.4)*
Retroperitoneal pressure (kPa)	1.5 (0.05)	1.4 (0.2)
AP systolic (kPa)	15.3 (2.6)	15.4 (1.7)
AP systolic (mm Hg)	115 (20)	116 (13)
AP diastolic (kPa)	9.1 (0.9)	9.2 (1.2)
AP diastolic (mm Hg)	68 (7)	69 (9)
HR (min^{-1})	67 (10)	69 (13)
CO (litre min^{-1})	4.9 (1.4)	5.6 (2.0)
CI (litre min^{-1} m^{-2})	2.5 (0.8)	2.8 (0.9)

in the deep block was in the SRS range 4–5 (good and excellent scores). Variability in the individual ratings was higher for a block with TOF=1–2 (mean coefficient of variation of ratings of surgical sessions 26%) compared with block with TOF=0 and PTC=1–2 (5%).

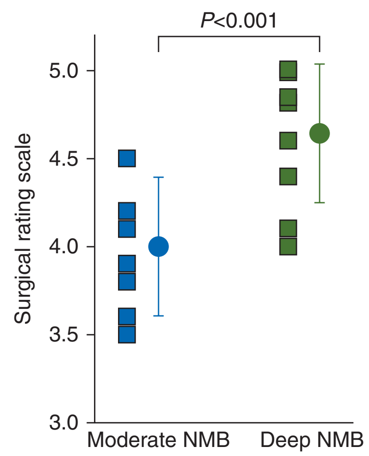

Fig 2 Surgical ratings by the surgeon during laparoscopic surgeries using the five-point SRS (see Table 1). Squares denote the individual mean ratings obtained during surgery. Circles are the mean of the means (SD). Standard indicates standard of care; deep NMB, deep neuromuscular block.

Measurements after surgery

Reversal of the NMB in patients with a deep block with sugammadex resulted in acceptable extubation conditions (TOF ratio >0.9) after 5.1 (2.4) min. In contrast, similar extubation conditions were obtained after 10.9 (4.9) min (P<0.01) in patients with TOF 1–2 and reversal with neostigmine. In the PACU, no differences were observed in respiration, pain, and sedation levels (Table 4).

Rating of surgical condition by anaesthetists

A random set of 10 video images was scored by 12 anaesthetists. The distribution of the surgeon's ratings of these 10 images is shown in Figure 4A; the corresponding distribution of ratings of the anaesthetists is shown in Figure 4B. Compared with the surgeon their ratings were skewed to the right and agreement with the surgeon's ratings was poor (agreement between scores ranged from 0 to 40%). The κ statistic was 0.05 (range −0.25 to 0.25). The Bland–Altman analysis resulted in a significant bias of −0.43 (0.21) (P=0.03) and large limits of agreement of 2.87 and −3.72, and a between-subject variance of 0.25 (Fig. 4C).

Discussion

This is the first study to assess the impact of a deep NMB (PTC 1–2) on surgical working conditions. The main results of our study are: (i) a deep NMB (TOF 0 and PTC 1–2) is associated with higher (i.e. improved) ratings from the surgeon compared with a moderate NMB (TOF 1–2) during laparoscopic prostatectomies and nephrectomies, indicating a significant improvement of surgical conditions; (ii) ratings from anaesthetists and surgeon of video images of the surgical field showed

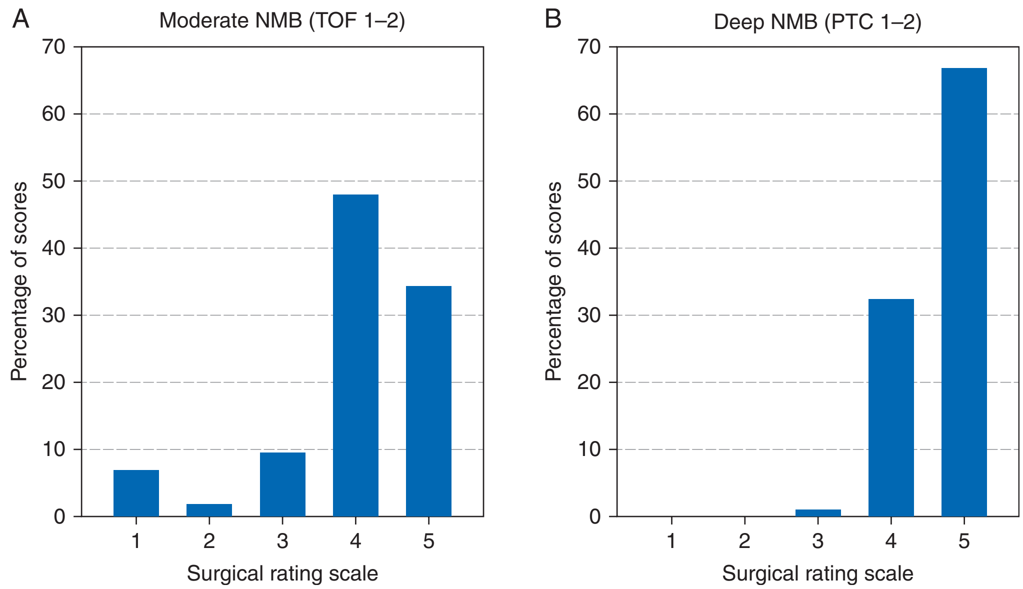

Fig 3 Distribution of the surgical ratings obtained during standard of care (A) and during deep NMB (B). NMB, neuromuscular block.

Table 4 Measurements after surgery. Values are mean (SD). TOF, train-of-four; PACU, post-anaesthesia care unit; Sp_{O_2}, arterial haemoglobin oxygen saturation

	Moderate NMB (TOF 1–2)	Deep NMB (PTC 1–2)
Sugammadex (mg)		380 (101)
Neostigmine (mg)	1 (0)	
Time to TOF ratio >0.9 (min)	10.9 (4.9)	5.1 (2.4)
Time in PACU (min)	86 (19)	86 (25)
Sp_{O_2} (%)	98.6 (1.8)	98.2 (1.4)
Breathing rate (min^{-1})	14.5 (2.2)	14.5 (2.2)
Pain score (10-point scale)	2.6 (1.6)	2.1 (2.2)
Sedation score (five-point scale)	2.0 (0.6)	1.3 (1.0)

little agreement. In the current study, we chose to study retroperitoneal laparoscopic surgeries for two urological procedures [prostatectomy and (partial) nephrectomy] as these procedures are confined to a narrow working space where adequate (deep) muscle relaxation is of high importance and an effect of less optimal muscle relaxation on the quality of the surgical field is rapidly apparent.

Surgical rating scale

The five-point rating scale used in our study was developed in close cooperation with the surgeon involved in our project, who has ample experience in the performed procedures. It was decided that while the scoring system should integrate all qualitative aspects that are important to the surgeon when judging the surgical working field, it should remain as simple as possible. A scoring system with >5 points was initially considered, such as an 11-point numerical quantitative scale (e.g. numerical rating or visual analogue scales from 0 to 10, cf. Ref. 8); however, it was decided to rank the surgical field qualitatively from extremely poor, via poor, acceptable, good to optimal conditions (see Table 1 for an explanation of the different ratings). Further, to reduce variability in scoring between assessors just one surgeon was requested to score the surgical field in our study. Our system is similar to other scoring systems. For example, the Clinical Global Impression (CGI) rating scale is a seven-point qualitative scale in which physicians rate the severity of a patient's mental illness relative to the physician's past experience.[11] The CGI and our scoring systems are subjective but in our case the ample experience of the surgeon gives credibility to the procedure. Indeed, the results of our study indicate that the surgeon was able to discriminate between a moderate and a deep NMB. The difference of 0.7 points (a difference of 18%) was regarded as important and clinically significant by the surgical team. We argue that the ability of our scoring system to discriminate between two distinct anaesthetic regimes indicates the validity of the five-point SRS we developed.

Still, our study should be considered a proof-of-concept trial and further validation of the SRS is mandatory. Therefore, one should be cautious in extrapolation of our results to other procedures and other surgeons. Other surgeons may rate the surgical condition differently and other procedures may require a different anaesthetic, surgical approach, or both. In an attempt to get an indication of the ability of other surgeons with ample experience in laparoscopic surgery to apply the scoring system, we invited eight surgeons, specialized in laparoscopic surgery for gastroenterological procedures, to score the 10 videos earlier presented to the anaesthetists. Their κ statistic was on average 0.50 indicative of moderate agreement. As

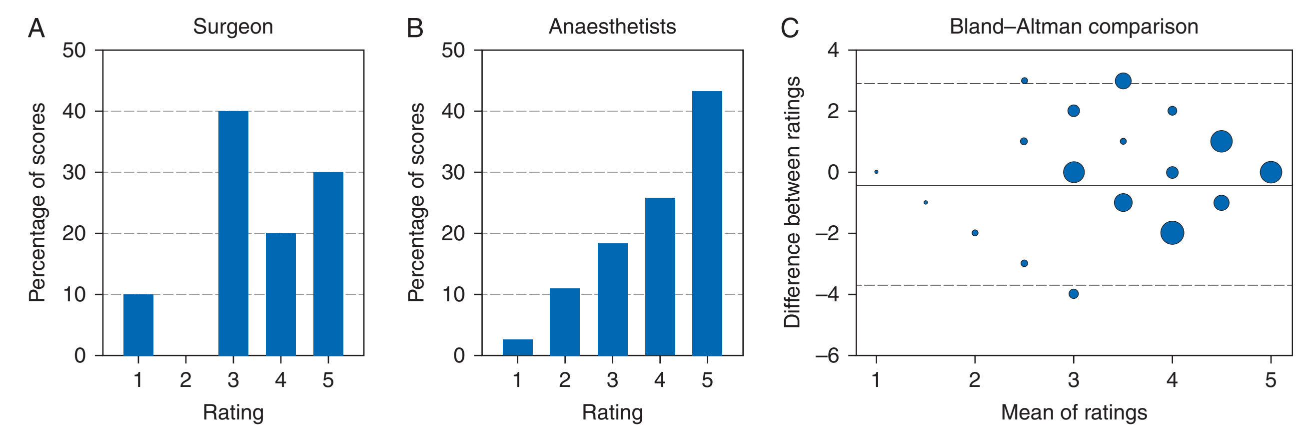

Fig 4 (A) Distribution of scorings obtained from a random sample of 10 video snippets scored by the surgeon. (B) Distribution of scorings obtained from a random sample of 10 video snippets scored by the surgeon a group of 12 anaesthetists. (C) Population Bland–Altman analysis of the scorings from anaesthetists and surgeon. The continuous horizontal line is the bias; the dotted line the limits of agreement. The size of the dots represents the number of (overlapping) data points, which range from 1 for the smallest dots (1, 0) and (1.5, −0.5), to 16 for the largest dot (4, −2).

expected, this agreement is substantially greater than that between surgeon and anaesthetists. It further shows that different surgeons (in this case with a different subspecialty) rate the surgical field differently. The current study was specifically aimed at scoring urological procedures performed in narrow retroperitoneal space. The results show a clinically relevant benefit of deep NMB for the surgeon involved in this study. Whether this benefit will also be relevant to other surgeons performing similar surgeries and possibly even for other laparoscopic procedures, such as for bariatric laparoscopic surgery is the topic of further research.

Deep neuromuscular block

Our *a priori* estimation of SRS distributions came close for the deep NMB but was underestimated for the moderate block. Good and optimal conditions were achieved during standard care (good 48% and optimal 34%) although at a lower frequency than during deep NMB (good 32% and optimal 67%). This indicates that in 82% of measurements during standard care and in 99% during deep NMB conditions were good to optimal. However, variability in ratings was high for moderate NMB compared with deep NMB: 26% *vs* 5%. Still, also in deep NMB, the range of scores (mean ranged from 4 to 5) was considered high and is still open for improvement. Possibly, further improvement may be obtained by (more) strictly controlling anaesthetic depth, analgesic state, and arterial carbon dioxide concentrations. In the current study, respirator settings were such that end-tidal carbon dioxide concentrations were between 4.4 and 6 kPa (33 and 56 mm Hg). High arterial carbon dioxide concentrations stimulate the respiratory neuronal pool in the brainstem, which activates the phrenic nerve.[12] As a consequence diaphragm contractions may persist despite a deep NMB. The NMB at the diaphragm is less intense than at the adductor pollicis muscle.[13 14] Indeed, some of the video images showed movement related to diaphragm contraction unrelated to the ventilator-induced inspiration–expiration sequence or cardiac contractions despite TOF values of zero. The surgeon scored such conditions at the low end of the SRS. In laparoscopic bariatric surgery, the working space volume and visibility increased in response to NMB.[15] In the current study, the retroperitoneal pressure was kept constant to 1.3–1.5 kPa (9–11 mm Hg) in both groups and it may be assumed that the working space volume was greater in the deep NMB group. However, the scoring by the surgeon is only in part based on the perceived volume of the retroperitoneal space. Other factors similarly influence the surgeon's working conditions and consequently play an additional role in his scoring. For example, muscle contractions (including the diaphragm) and resultant movement of other structures are important as well. Further studies should address these issues.

We tested deep *vs* moderate block using two different drug regimens. The reason for this was that this approach enabled us to compare our current practice with atracurium and mivacurium with an approach that not only allows us to induce a deep NMB but also allows rapid reversal of that deep block. As our end point was to compare the depth of the NMB irrespective of the drugs used to induce that state, we do not believe that this influenced our outcome significantly. We observed that full reversal after deep NMB occurred after 5 min. It is important, however, to realize that measurements were made at 5 min intervals and full reversal with TOF ratios >0.9 may have occurred earlier (for sugammadex reversal to TOF ratio >0.9 is expected after 2–3 min).

Scoring by anaesthetists of the surgical field

An important finding in our study is that the agreement of scores between the anaesthetists and surgeon was poor. This indicates that the anaesthetists are less well able to measure the quality of surgical conditions from the video images and hence derive insufficient information from these images regarding the working conditions of the surgeon. It may be argued that in our study observing a 30 s video image does not provide sufficient input to assess the quality of surgical condition in non-surgically skilled personnel. This certainly may be true, but in our study, and possibly also in clinical practice, the anaesthetists base their impression of the surgical field primarily on the volume of the working space and the visibility of retroperitoneal tissues (most importantly related to the absence or presence of blood in the image obscuring relevant structures) without addressing muscle contractions and other movements visible on the video image. In our hospital, live video images of the laparoscopic field are presented to the anaesthetists during each case and these, together with his/her clinical experience and interaction with the surgeon, form the basis of the anaesthetic regimen, including the additional use of neuromuscular blocking agents when surgical conditions are deemed poor. Some anaesthetists may not be willing to induce a deep NMB. This may be related to their inability to adequately judge the operating field from the video screen but additionally to their fear for suboptimal post-surgical conditions. Evidently, this may be the cause of some discussion in the operating theatre. To prevent such situations, we suggest that surgeons and anaesthetists communicate their wishes and intentions before the procedure (e.g. during preoperative *time-out*) and closely cooperate in obtaining optimal working conditions. Here, we show that providing a deep NMB improves surgical conditions.

Authors' contributions

C.M. was involved in the conception of the study idea and design of the study. He performed part of the experiments, participated in the data analysis, and writing of the paper. M.B. participated in the writing of the protocol, performed part of the experiments, and participated in the writing of the paper. R.F.B. was involved in the design of the study and participated in the development of the surgical rating scale, performed all surgeries, and scored the quality of the surgical field at 15 min intervals. L.P.A. was involved in the writing of the protocol and the interpretation of the results, and writing of the paper. A.D. was involved in the inception of the study idea, the design of the study, wrote the protocol, performed part of the experiments, analysed the data, interpreted the results, and wrote the paper.

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Declaration of interest

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