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Ergonomic assessment of the French and American position for laparoscopic cholecystectomy in the MIS Suite

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Abstract
Background Cholecystectomy was one of the first surgical procedures to be performed with laparoscopy in the 1980s. Currently, two operation setups generally are used to perform a laparoscopic cholecystectomy: the French and the American position. In the French position, the patient lies in the lithotomy position, whereas in the American position, the patient lies supine with the left arm in abduction. To find an ergonomic difference between the two operation setups the movements of the surgeon's vertebral column were analyzed in a crossover study.
Methods The posture of the surgeon's vertebral column was recorded intraoperatively using an electromagnetic motion-tracking system with three sensors attached to the head and to the trunk at the levels of Th1 and S1. A three-dimensional posture analysis of the cervical and thoracolumbar spine was performed to evaluate four surgeons removing a gallbladder in the French and American position. The body angles assessed were flexion/extension of the cervical and thoracolumbar spine, axial rotation of the cervical and thoracolumbar spine, lateroflexion of the cervical and thoracolumbar spine, and the orientation of the head in the sagittal plane. For each body angle, the mean, the percentage of operation time within an ergonomic acceptable range, and the relative frequencies were calculated and compared.
Results No statistical difference was observed in the mean body angles or in the percentages of operation time within an acceptable range between the French and the American position. The relative frequencies of the body angles might indicate a trend toward slight thoracolumbar flexion in the French position.
Conclusion In a modern dedicated minimally invasive surgery suite, the body posture of the neck and trunk and the orientation of the head did not differ significantly between the French and American position.

Keywords Minimally invasive surgery · French position · American position · Laparoscopic cholecystectomy · Ergonomics · Posture

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Since the late 1980s, cholecystectomy has been performed with a laparoscopic technique, and this currently is the gold standard. Laparoscopic surgery has several established advantages including less blood loss, decreased postoperative pain, a shorter hospital admission time, quicker reintroduction into society, and superior cosmetic results [1–4].

On the other hand, laparoscopic techniques confront the surgeon and the surgical team with ergonomic challenges. During laparoscopy, the surgeon works with a diversion of the working field and line of vision. This diversion of the visual and working axis can create awkward static postures including rotation of the spine, extension of the neck, and elevation of the upper extremities and might compromise surgical task performance [5–8].

In recent research, approximately 87 % of surgeons involved in laparoscopy reported musculoskeletal problems [5]. Ergonomic studies suggest that a balance should be maintained between optimal comfort and safety on one

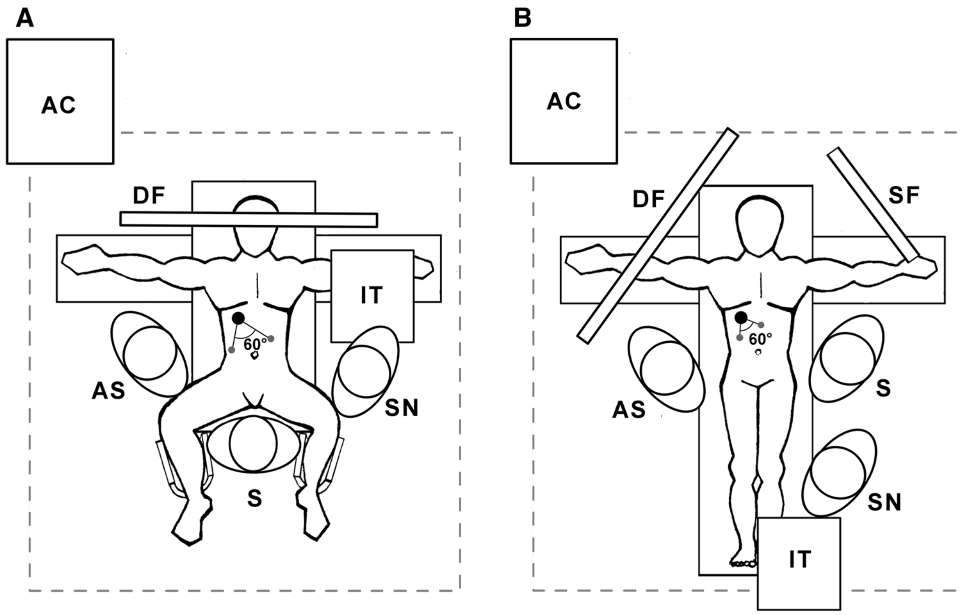

Fig. 1 Room setup in dedicated minimally invasive surgery (MIS) suites with suspended monitors. **A** The French position. **B** The American position. *AC* anesthesia console, *DF* double flat screen, *SF* single flat screen, *S* operating surgeon, *AS* assisting surgeon, *SN* scrub nurse, *IT* instrument table. *Black dot* Location of the gallbladder. *Gray dots* Locations of the instrument ports. In both positions, the optic port is located at the umbilicus. The two instrument ports are inserted at anatomic locations that enable a manipulation angle of 60°. The axis of the camera is between the axes of the working instruments. 108 × 139 mm (300 × 300 DPI)

hand and optimal effectiveness and efficiency on the other hand [9]. To achieve this, the operating room has to be set up and the patient has to be positioned such that these conditions can be accommodated [9, 10].

For laparoscopic cholecystectomy, two setups are widely used worldwide: the so-called French position and the American position (Fig. 1). The preferred setup of surgeons is based on locoregional common practice. To find evidence for the most ergonomic position, this study was conducted to compare body posture differences among surgeons performing a laparoscopic cholecystectomy in the French and American position.

Materials and methods

Study design

The ergonomic qualities of the surgeon's posture in the French and American position were compared during laparoscopic cholecystectomy in a crossover design. An intraoperative motion analysis was performed during laparoscopic cholecystectomies for patients with symptomatic uncomplicated gallbladder disease.

Participating surgeons

Four surgeons (2 residents and 2 consultants) were recruited to perform the procedures in both setups (Table 1). The residents were in their 5th and 6th years of their surgical training, performing laparoscopic cholecystectomy frequently and independently.

Table 1 Education and level of experience of the participants

Surgeon	Education	Level of experience
A	American	Resident
B	American	Consultant
C	French	Resident
D	French	Consultant

The consultants were certified gastrointestinal surgeons with extensive experience in laparoscopic techniques. One consultant and one resident, originally trained in the Netherlands using the American position, were educated to perform laparoscopic cholecystectomy in the French position. The remaining two surgeons, originally trained in Belgium using the French position, were educated in the American position. Each of the four participants were required to perform one procedure in each position. All the surgically treated patients gave informed consent.

Operative setup

All procedures were performed in a dedicated minimally invasive surgery (MIS) suite with permanently installed multiple flat-screen monitors attached to a ceiling-mounted suspension system. The monitor and operation table were organized to create an ergonomic workspace. The monitors were positioned according to the following guidelines [9, 10]:

(1) Straight in front of the subject in the horizontal plane to avoid rotation of the vertebral column
(2) In a downward viewing direction between 10° and 30° in the sagittal plane to optimize task performance

and at the same time prevent fatigue of the neck muscles

(3) At a proper viewing distance (80–120 cm), close enough to avoid loss of detail and at the same time far enough to avoid eye strain due to constant accommodation.

The table was positioned between 70 % and 80 % of the elbow height of the surgeon to avoid extreme excursions of the upper extremities [10].

For the French position, the patient is placed in the supine position with the perineum at the edge of the table, the hips and knees flexed, and the left arm or both arms in abduction. The operating surgeon stands between the legs, the assisting surgeon standing on the right side of the patient and the scrub nurse standing on the left side (Fig. 1A). The patient is turned in reversed Trendelenburg position. For the American position, the patient also is placed in the supine position, with the left arm or both arms in abduction. The operating surgeon stands on the left side of the patient, with the scrub nurse on the left side of the operating surgeon and the assisting surgeon on the right side (Fig. 1B). The patient is turned in reversed Trendelenburg position and slightly to the left. For both positions, a four-port technique is used. The optical (primary) port is located at the umbilicus. The two operating (secondary) ports are inserted at locations that enable a manipulation angle of 60° between the tips of the instruments to imitate the natural relationship between the hands as far as possible. The axis of the camera is placed between the axes of the working instruments [11]. As a consequence of the surgeon's change in the location between the two operation positions the instrument port location is different between the two operation setups (Fig. 1).

Motion tracking

Measurements of the body movements were performed using the Flock of Birds real-time motion tracking device (Ascension Technology Corporation, Milton, Massachusetts, USA). The Flock of Birds real-time motion tracking system consists of a transmitter placed behind the participant, three sensors attached to the body, and hardware units connected to the sensors, the transmitter, and a laptop computer (Fig. 2A). The sensors were attached to the head with a headband, to the skin at the level of spinous process Th1, and to the body of the sacrum S1 of the participant to track the movements.

The transmitter of the motion-tracking device creates an electromagnetic field. The motion tracker uses this electromagnetic field to determine the orientation of the sensors in relation to the x-axis, y-axis, and z-axis of the transmitter

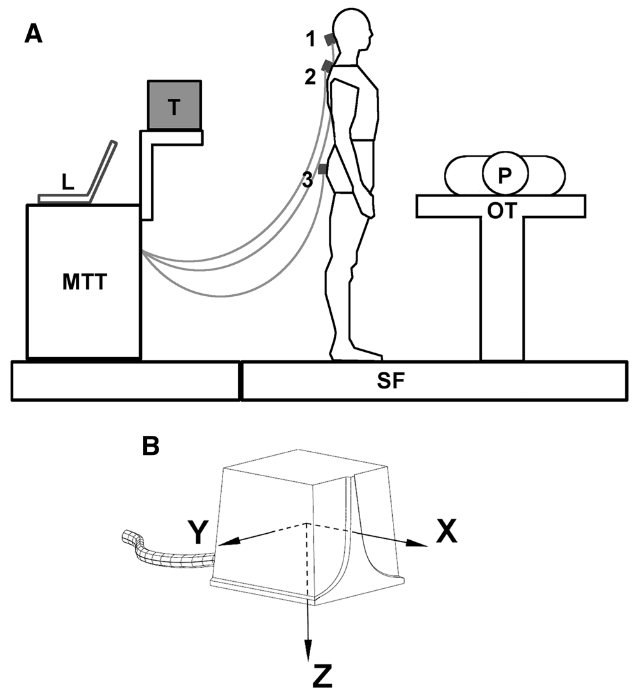

Fig. 2 The motion-tracking device setup. **A** Attachment of the sensors to the operating surgeon. MTT, motion-tracker trolley; T, transmitter; SF, sterile field; L, laptop; P, patient; OT, operation table. One sensor on the head, two sensors on Th1, and three sensors on S1 are shown. **B** A sensor with projection of the axes used to calculate the body angles. Drawing courtesy of Ascension Technology Corporation. Used with permission. 25 × 17 mm (300 × 300 DPI)

using the Euler format (roll, elevation, and azimuth) (Fig. 2B). By calculating the difference between the orientation of two sensors, the angles of the cervical and thoracolumbar spine can be accurately determined in three dimensions.

Before scrubbing, the sensors were mounted to the head and body of the participating surgeon. The surgical gown could be worn over the sensors, so the sterile environment was not compromised during the measurements. The motion-tracking software was configured to measure the body posture with an interval of approximately 0.33 s.

The recording was started at the introduction of the trocars and stopped at the moment of gallbladder extraction. The phases between these moments (preparation, clipping, gallbladder dissection, and coagulation-suction) consist mainly of long static-posture episodes disrupted by short intervals of instrument changes when the extremities and the torso move. Research has shown that within these phases, approximately 75 % of the time is spend in a static body posture [8]. It is believed that the prolonged awkward postures during these long static-posture episodes are the main cause of neck and back problems in laparoscopic surgery.

Ergonomic principles

Because postures during laparoscopic procedures are more static than during open surgery, physical problems can arise when postures are not within an ergonomic neutral range. To estimate the ergonomic quality of the surgeon's posture, rotations in the thoracolumbar and cervical spines were calculated for the three anatomic planes: (1) the horizontal plane (axial rotation), (2) the sagittal plane (flexion/extension), and (3) the coronal plane (lateroflexion).

Additionally we measured the orientation of the head in the sagittal plane to qualify the extent of "gaze-down viewing" in relation to the monitor position. The orientation of the head is the end product of the spine's posture and closely related to the position of the monitor.

For this study, the following optimal ergonomic body posture was chosen:

- Minimal axial rotation and lateroflexion in both the thoracolumbar and cervical spines
- Neutral position or slight flexion in the thoracolumbar and cervical spines
- Achievement of a "gaze-down" orientation of the head toward the operating field.

Data analysis

Neutral body posture

To calculate the angles of the vertebral column and the orientation of the head in neutral body posture, 15–25 reference measurements were recorded, with the operator instructed to stand in a neutral body posture: feet slightly apart, back and neck upright, arms alongside the body, and eyes focusing on a point at eye height on the opposite wall of the operating room. The mean angles and orientation were calculated and designated as neutral reference values for the body posture of the surgeon performing laparoscopic cholecystectomy in the French or American position.

Working body posture

Flexion/extension of the cervical and thoracolumbar spine CspineF/E and TLspineF/E at each time point were calculated using the following formulas:

$$[\text{CspineF/E}]_{\text{workingposture}} = \left([\text{sagittal plane}]_{\text{head}} - [\text{sagittal plane}]_{\text{Th1}}\right) - \left([\text{sagittal plane}]_{\text{head}} - [\text{ Sagittal plane}]_{\text{Th1}}\right)_{\text{neutral}}$$

$$[\text{TLspineF/E}]_{\text{workingposture}} = \left([\text{sagittal plane}]_{\text{Th1}} - [\text{sagittal plane}]_{\text{S1}}\right) - \left([\text{sagittal plane}]_{\text{Th1}} - [\text{ Sagittal plane}]_{\text{S1}}\right)_{\text{neutral}}$$

Negative values indicate flexion and positive values indicate extension.

Torsion of the cervical and thoracolumbar spine NeckT and BackT at each time point were calculated using the following formulas:

$$[\text{CspineT}]_{\text{workingposture}} = \left([\text{transversal plane}]_{\text{head}} - [\text{transversal plane}]_{\text{Th1}}\right) - \left([\text{transversal plane}]_{\text{head}} - [\text{transversal plane}]_{\text{Th1}}\right)_{\text{neutral}}$$

$$[\text{TLspineT}]_{\text{workingposture}} = \left([\text{transversal plane}]_{\text{Th1}} - [\text{transversal plane}]_{\text{S1}}\right) - \left([\text{transversal plane}]_{\text{Th1}} - [\text{transversal plane}]_{\text{S1}}\right)_{\text{neutral}}.$$

Lateroflexion of the cervical and thoracolumbar spine CspineLF and TLspineLF at each time point were calculated using the following formulas:

$$[\text{CspineLF}]_{\text{workingposture}} = \left([\text{frontal plane}]_{\text{head}} - [\text{frontal plane}]_{\text{Th1}}\right) - \left([\text{frontal plane}]_{\text{head}} - [\text{frontal plane}]_{\text{Th1}}\right)_{\text{neutral}}$$

$$[\text{TLspineLF}]_{\text{workingposture}} = \left([\text{frontal plane}]_{\text{Th1}} - [\text{frontal plane}]_{\text{S1}}\right) - \left([\text{frontal plane}]_{\text{Th1}} - [\text{frontal plane}]_{\text{S1}}\right)_{\text{neutral}}.$$

Orientation of the head in the sagittal plane HeadOSP at each time point was calculated using the following formula:

$$[\text{HeadOSP}]_{\text{workingposture}} = [\text{sagittal plane}]_{\text{head}} - [\text{sagittal plane}]_{\text{neutralhead}}.$$

Statistical analyses

A Wilcoxon signed-rank test was used to compare the mean operating time of the French with the American position. The same statistical test was used to compare the body posture and the percentage of operation time within an ergonomically acceptable range. In all comparisons, a p value lower than 0.05 was considered statistically significant. To calculate the variance in the working body posture of the individual surgeons, the analysis of variance (ANOVA) formula for pooled variance was used to calculate the pooled standard deviation. The data was processed with SPSS 20.0.0.1 (SPSS, Chicago, IL, USA).

Table 2 Mean body angles in the sagittal, horizontal, and coronal plane[a]

Sagittal plane							
CspineF/E				TLspineF/E			
	French	American	*p* Value		French	American	*p* Value
Mean	1.9 ± 5.6	–3.4 ± 5.6	0.273	Mean	–5.4 ± 4.0	–1.9 ± 3.3	0.273
Horizontal plane							
CspineT				TLspineT			
	French	American	*p* Value		French	American	*p* Value
Mean	–0.4 ± 6.2	–0.3 ± 7.5	0.715	Mean	3.2 ± 4.9	–2.9 ± 3.9	0.465
Coronal plane							
CspineLF				TLspineLF			
	French	American	*p* Value		French	American	*p* Value
Mean	1.3 ± 5.1	3.0 ± 6.1	0.144	Mean	–2.2 ± 4.6	0.7 ± 5.1	0.465

Values are expressed as degrees ± standard deviation

Results

Data characteristics

The mean recording time was 20.8 min per procedure and did not differ between the French and American procedures (21.6 vs 20.0 min; $p = 0.715$). Each of the four surgeons performed one laparoscopic cholecystectomy each in the French and American position in random order. No complications occurred, and all the procedures could be completed laparoscopically. All the patients were discharged from the hospital without any adverse events the day after the procedure.

Mean body angles

Table 2 shows the mean body angles for the different movement directions during the laparoscopic cholecystectomy in the French and American position. No statistically significant difference was found between the French and American position in terms of cervical spine flexion/extension ($p = 0.273$), thoracolumbar spine flexion/extension ($p = 0.273$), cervical spine torsion ($p = 0.715$), thoracolumbar spine torsion ($p = 0.465$), cervical spine lateroflexion ($p = 0.144$), or thoracolumbar spine lateroflexion ($p = 0.465$).

Relative frequencies and percentage of operation time within an ergonomic acceptable range

To obtain insight into the percentage of time spent within different body angle ranges, the relative frequencies of the body angles were calculated. The relative frequency histograms of the cervical and thoracolumbar angles in the sagittal, horizontal, and coronal planes are represented in Figs. 3, 4, 5, and the head orientation is represented in Fig. 6.

Regarding the operating time within an ergonomic acceptable range in the sagittal plane, no significant difference was found in the cervical spine (French position, 71.5 %; American position, 71.5 %; $p = 0.273$) or in the thoracolumbar spine (French position, 97.5 %; American position, 95.1 %; $p = 0.715$).

In the horizontal plane, no significant differences were found in the percentage of operating time within an ergonomically acceptable range in the cervical spine (French position, 97.0 %; American position, 82.8 %; $p = 0.144$) or in the thoracolumbar spine (French position, 94.7 %; American position, 98.6 %; $p = 0.144$).

In the coronal plane, no significant differences were found in the percentage of operating time within an ergonomically acceptable range in the cervical spine (French position, 98.4 %; American position, 97.0 %; $p = 0.715$) or in the thoracolumbar spine (French position, 98.3 %; American position, 97.4 %; $p = 1.000$).

Head orientation in the sagittal plane

Table 3 shows the results for the head orientation in the sagittal plane. The French and the American position did not differ in terms of the head orientation in the sagittal plane ($p = 0.465$).

Discussion

Laparoscopic surgery provides well-established advantages for the patient, but the operating team is confronted with

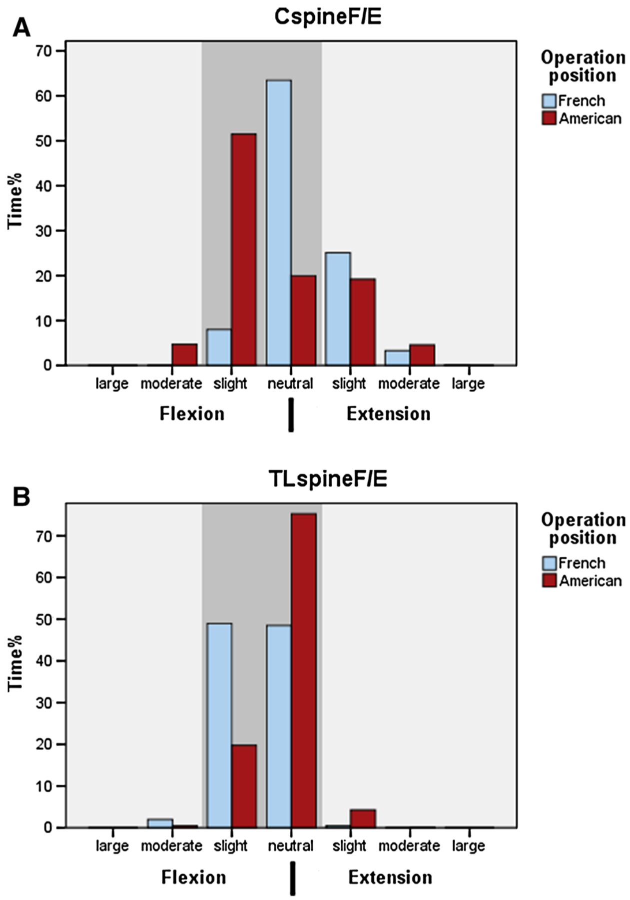

Fig. 3 Relative frequency histograms showing flexion/extension of (**A**) the cervical spine (CspineF/E) and (**B**) the thoracolumbar spine (TLspineF/E). The body angles in the sagittal plane are categorized as large flexion (≥35°), moderate flexion (–35° to –15°), slight flexion (–15° to –5°), neutral position (–5° to +5°), slight extension (+5° to +15°), moderate extension (+15° to +35°), and large extension (>+35°). The *gray-colored* area indicates the ergonomic acceptable range (–15° flexion to 5° extension). 40 × 28 mm (300 × 300 DPI)

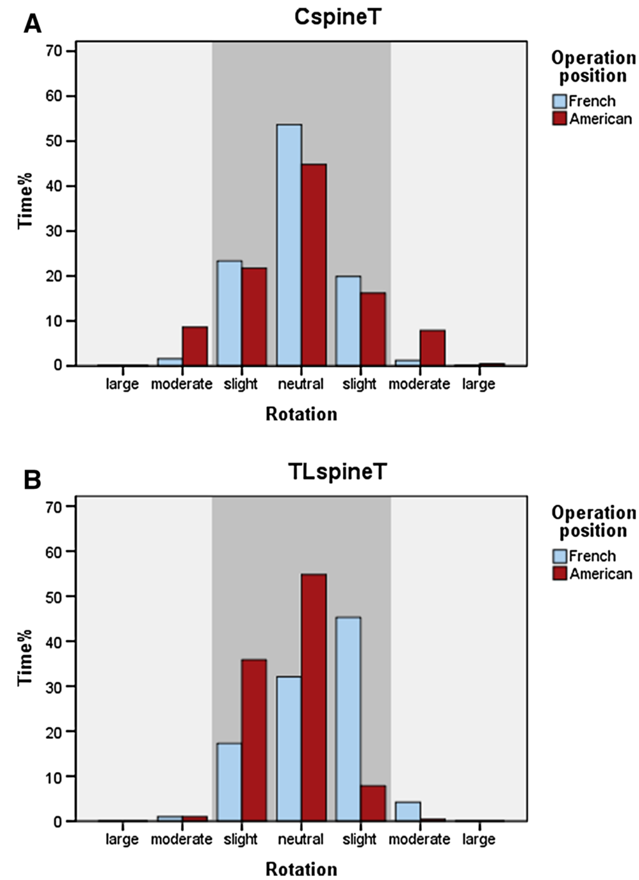

Fig. 4 Relative frequency histograms showing axial rotation of (**A**) the cervical spine (CspineT) and (**B**) the thoracolumbar spine (TLspineT). Rotation is categorized as neutral position (–5° to +5°), slight rotation (5° to 15°), moderate rotation (15° to 35°), and large rotation (>35°). The *gray-colored* area indicates the ergonomic acceptable range (<15°). 40 × 28 mm (300 × 300 DPI)

ergonomic challenges. This study compared the ergonomic quality of the surgeon's body posture and the pattern of postural changes during laparoscopic cholecystectomy performed in the French and American position. To our knowledge, this was the first study to use an intraoperative motion-tracking device to perform a three-dimensional measurement of the surgeon's body posture during a laparoscopic cholecystectomy in a MIS suite.

Motion analysis of the vertebral column suggested that the surgeon's posture does not differ significantly between the French and the American position in a MIS suite. Furthermore, no statistical significant difference was found in the percentages of the time surgery was performed within an ergonomic acceptable range. In both positions, most of the time was spent within an ergonomic acceptable range. This is in contrast with results of research that assessed the ergonomics of the two operating positions in a virtual reality simulator [12]. The results of this study indicated better ergonomics of the vertebral column and upper extremities in the French position. A possible explanation for the discrepancy in results between this study and the current study is the adjustability of the multiple suspended monitors in the MIS suite. By adjusting the position of the monitor in the MIS suite, the surgeon's tendency to rotate the cervical and thoracolumbar spine in the American position might have been minimized to an acceptable level.

Although not statistically significant, the relative frequency histogram of cervical flexion suggests that the neck of the surgeon may be slightly more flexed for a higher percentage of the operating time in the American position (51.5 %) than in the French position (8.0 %). In the posture of the back, the contrary is found. The back is slightly more flexed for a higher percentage of the time in the French position (49.0 %) than in the American position (19.8 %). On the basis of the team positioning, we could reason that

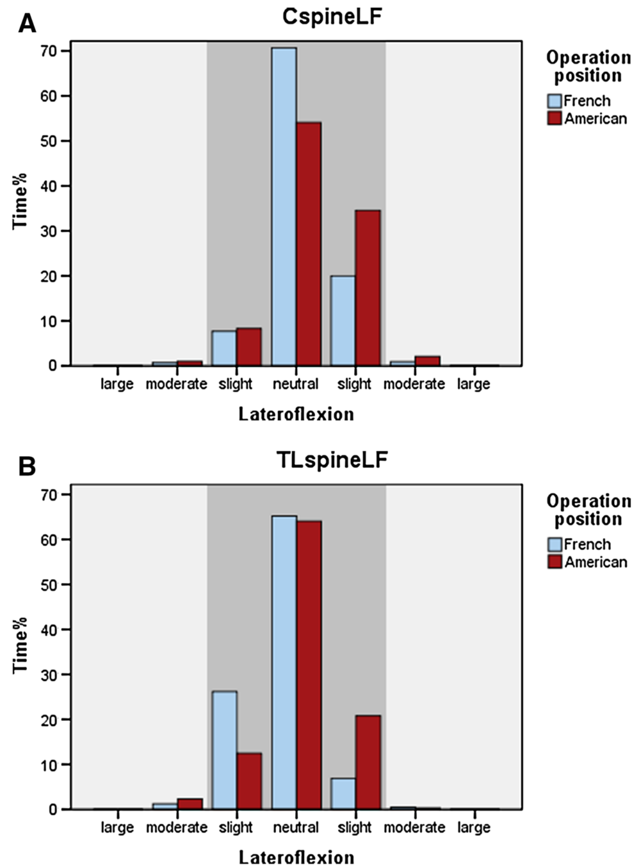

Fig. 5 Relative frequency histograms showing lateroflexion in (**A**) the cervical spine (Cspine LF) and (**B**) the thoracolumbar spine (TLspineLF). Lateroflexion is categorized as neutral position (–5° to +5°), slight lateroflexion (5° to 15°), moderate lateroflexion (15° to 35°), and large lateroflexion (>35°). The *gray-colored* area indicates the ergonomic acceptable range (<15°). 40 × 28 mm (300 × 300 DPI)

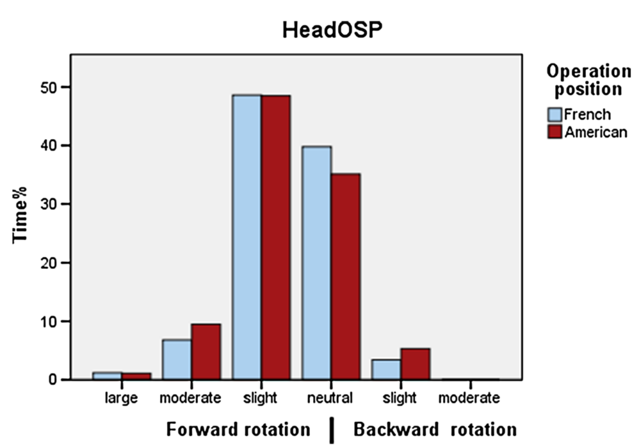

Fig. 6 Relative frequency histogram showing the orientation of the head (HeadOSP). The orientation angles are categorized as large forward rotation (≥25°), moderate forward rotation (–25° to –15°), slight forward rotation (–15° to –5°), neutral position (–5° to +5°), slight backward rotation (+5° to +15°), and moderate backward rotation (+15° to +25°). 40 × 28 mm (300 × 300 DPI)

Table 3 Mean head orientation in the sagittal plane

HeadOSP			
	French	American	p Value
Mean	–6.3 ± 5.6	–6.3 ± 5.6	0.465

[a] Values are expressed as degrees ± standard deviation

the slight thoracolumbar flexion in the French position could be caused by a greater distance between the surgeon and the operating field in the French position. This distance has to be bridged by a slight bending forward. The thoracolumbar flexion forward leads in turn to a decreased flexion of the neck in the French position compared with the American position. However, because the adaptation of the thoracolumbar spine to the work environment is within an ergonomic acceptable range (–15° flexion to 5° extension), the surgeon probably faces no increased risk of musculoskeletal problems.

Different variables can influence the neutral and working body postures in the operating room. For instance, in a study examining the ergonomic aspects of laparoscopic surgery, surgeons with less than 2 years experience were significantly more affected by ergonomically inefficient environments in the operation room than those with longer experience [7].

We tried to minimize the effects of these variables in two ways: on the basis of experience (a group of two residents and two experienced surgeons were selected) and on the basis of education (one resident and one experienced surgeon were educated in the French, whereas the remaining resident and experienced surgeon were educated in the American position). Furthermore, the crossover design used in this study made it possible to correct for individual differences in working body posture between the participating surgeons. A weakness of this study and a potential hazard for types 1 and 2 errors was the small sample size.

Some ergonomic issues could not be answered with this study. First, the relation between the surgeon's body length and body posture during surgery was not investigated. Theoretically, in the French position, the work field is further away from the surgeon. Therefore, a tall surgeon with long upper extremities can bridge this distance to the operating field easier while maintaining a straight back posture. Second, the size of the patient was not taken into account. The distance between the work field and the surgeon increases as the size of the patient increases. Therefore, a procedure on a tall patient could lead to a less comfortable posture of the vertebral column. Considering the position of the surgeon in the operating team, this could especially be the case in the French position. Third, in this study, only the spine was taken into account. Additional in vivo measurements of the shoulder, arm, and wrist angles could provide more information about the amount of strain on the upper body in the French and American position in a MIS suite. This could be particularly interesting for the American position, in which the surgeon has the tendency to hold his upper extremities in an uncomfortable position due to the location of the instrument ports and the angle of the axes of the instruments [12]. To demonstrate the importance of these factors during live operations, further studies are necessary. Nonetheless, this comparative study indicates that the posture of the vertebral column and the head orientation in the sagittal plane do not differ significantly between the French and American position in a modern MIS suite.

Disclosures Kelvin H. Kramp, Marc J. van Det, Eric R. Totte, Christiaan Hoff, and Jean-Pierre E. N. Pierie have no conflicts of interest or financial ties to disclose.

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