Education in laparoscopic surgery
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Chapter 4

ERGONOMIC ASSESSMENT OF THE FRENCH AND AMERICAN POSITION FOR LAPAROSCOPIC CHOLECYSTECTOMY IN THE MIS SUITE

Kelvin H. Kramp, Marc J. van Det, Eric R. Totte, Christiaan Hoff, Jean-Pierre E.N. Pierie

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Abstract

**Aims:** The cholecystectomy was one of the first surgical procedures to be performed with laparoscopy in the 1980s. Nowadays, there are generally two operation setups to perform a laparoscopic cholecystectomy: the French and the American position. In the French position the patient lies in the lithotomy position, while in the American position the patient lies supine with the left arm in abduction. In order to find an ergonomic difference between the two operation setups the movements in the vertebral column of the surgeon were analyzed in this crossover study.

**Methods:** The posture of the surgeon’s vertebral column was recorded intra-operatively using an electromagnetic motion tracking system with three sensors attached to the head and to the trunk at the level of Th1 and S1. A three-dimensional posture analysis of the cervical and thoracolumbar spine was conducted on 4 surgeons performing a laparoscopic cholecystectomy in the French and in the American position. The body angles that were assessed consisted of: flexion/extension of the cervical and the 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 time percentage within an ergonomic acceptable range and the relative frequencies were calculated and compared.

**Results:** No statistical differences were observed in the mean body angles and time percentages within an acceptable range between the French and the American position. The relative frequencies of the body angles might indicate a trend towards slight cervical flexion in the American position and slight thoracolumbar flexion in the French position.

**Conclusion:** In a modern dedicated minimally invasive surgery suite, there were no significant differences in body posture of the neck and trunk and orientation of the head between the French and American position.
Introduction

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 post-operative pain, a shorter hospital admission time, quicker reintroduction into society, and superior cosmetic results. 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. In recent research, approximately 87% of surgeons involved in laparoscopy reported musculoskeletal problems.

Ergonomic studies suggest that a balance should be maintained between optimal comfort and safety on one hand and optimal effectiveness and efficiency on the other hand. 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. For the laparoscopic cholecystectomy, two setups are widely used worldwide: the so-called French position and the American position (Figure 1). The preferred setup of surgeons is based on locoregional common practice. 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.

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.

Table 1: Education and level of experience of the participants

<table>
<thead>
<tr>
<th>Surgeon</th>
<th>Education</th>
<th>Level of experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>American</td>
<td>Resident</td>
</tr>
<tr>
<td>B</td>
<td>American</td>
<td>Consultant</td>
</tr>
<tr>
<td>C</td>
<td>French</td>
<td>Resident</td>
</tr>
<tr>
<td>D</td>
<td>French</td>
<td>Consultant</td>
</tr>
</tbody>
</table>

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:

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.

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 (Figure 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 (Figure 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
degrees 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. 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 (Figure 1).

![Figure 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.](image)

**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 (Figure 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 using the Euler format (roll, elevation, and azimuth) (Figure 2b). By calculating the difference between the orientation of two sensors, the angles of the cervical and thoracolumbar spine can be 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 spent in a static body posture. 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**

Postural muscles are always active while standing to counteract the forces exerted by gravity on the body mass. The activity of the muscles is minimized when the body parts are in a vertical line and the moments produced by gravity are at a minimum. The activity of the muscles around the cervical vertebral column is mainly determined by the weight and position of the head and the tension in the ligaments. Prolonged extreme forward flexion (>30 degrees) can cause complaints of the neck muscles. Extension is done when looking upward. An upward gaze causes higher load on the ocular muscle and is hypothesized to enlarge the ocular surfaces leading to visual strain due to increased tear vaporisation. Rotation of the neck further than 35 degrees causes the muscle load to increase dramatically.

Flexion and extension of the back is mainly facilitated in the lumbar spine. The activity of the associated back muscles is likewise determined by weight and position of the trunk. Flexion is initiated by the abdominal muscles and the iliopsoas and maintained by the m. erector spinae during a static posture. The abdominal muscles assist in flexion by increasing the abdominal pressure and producing an abdominal spring force, thereby reducing the work needed by the m. erector spinae.
needed to maintain flexion. Research indicates there is an increased prevalence of low back pain in workers who have to bend or twist their back during labour hours.

**Ergonomic assessment**

To estimate the ergonomic quality of the surgeon’s posture, rotations in the thoracolumbar and cervical spines were calculated for the three anatomic planes:

- The horizontal plane (axial rotation)
- The sagittal plane (flexion/extension)
- 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**

**A. Flexion/extension of the cervical and thoracolumbar spine**

\[ \text{CspineF/E}_{\text{working posture}} = (\text{Sagittal plane}_{\text{head}} - \text{Sagittal plane}_{\text{Th1}}) - (\text{Sagittal plane}_{\text{head}} - \text{Sagittal plane}_{\text{Th1}})_{\text{neutral}} \]

**B. Torsion of the cervical and thoracolumbar spine**

\[ \text{ NeckT}_{\text{working posture}} = (\text{Transversal plane}_{\text{head}} - \text{Transversal plane}_{\text{Th1}}) - (\text{Transversal plane}_{\text{head}} - \text{Transversal plane}_{\text{Th1}})_{\text{neutral}} \]

**C. Lateroflexion of the cervical and thoracolumbar spine**

\[ \text{CspineLF}_{\text{working posture}} = (\text{Frontal plane}_{\text{head}} - \text{Frontal plane}_{\text{Th1}}) - (\text{Frontal plane}_{\text{head}} - \text{Frontal plane}_{\text{Th1}})_{\text{neutral}} \]

**D. Orientation of the head in the sagittal plane**

\[ \text{HeadOSP}_{\text{working posture}} = \text{Sagittal plane}_{\text{head}} - \text{Sagittal plane}_{\text{neutral head}} \]
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).
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). 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).

Table 2: Mean body angles in the sagittal, horizontal and coronal plane (values in degrees +/- SD)

<table>
<thead>
<tr>
<th>Sagittal plane</th>
<th>CspineF/E</th>
<th>TLspineF/E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>French</td>
<td>American</td>
</tr>
<tr>
<td>Mean</td>
<td>1.9±5.6</td>
<td>-3.4±5.6</td>
</tr>
<tr>
<td>Horizontal plane</td>
<td>CspineT</td>
<td>TLspineT</td>
</tr>
<tr>
<td></td>
<td>French</td>
<td>American</td>
</tr>
<tr>
<td>Mean</td>
<td>-0.4±6.2</td>
<td>-0.3±7.5</td>
</tr>
<tr>
<td>Coronal plane</td>
<td>CspineLF</td>
<td>TLspineLF</td>
</tr>
<tr>
<td></td>
<td>French</td>
<td>American</td>
</tr>
<tr>
<td>Mean</td>
<td>1.3±5.1</td>
<td>3.0±6.1</td>
</tr>
</tbody>
</table>

Relative frequencies and time percentage of operation time within 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 figures 3 and the head orientation is represented in Figure 4.

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).

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 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).
Figure 3a: Relative frequency histograms showing flexion/extension of the cervical (CspineF/E) and thoracolumbar (TLspineF/E) spine. The body angles in the sagittal plane are categorized in large flexion (lower than -35 degrees), moderate flexion (-35 to -15 degrees), slight flexion (-15 to -5 degrees), neutral position (-5 to +5 degrees), slight extension (+5 to +15 degrees), moderate extension (+15 to +35 degrees) and large extension (higher than +35 degrees). The gray coloured columns indicate the ergonomically acceptable range (-15° flexion to 5° extension).

Figure 3b: Relative frequency histograms showing axial rotation in the cervical (CspineT) and thoracolumbar (TLspineT) spine. Rotation is categorized in neutral position (-5 to +5 degrees) and in slight rotation (5 to 15 degrees), moderate rotation (15 to 35 degrees) and large rotation (higher than 35 degrees). The gray coloured columns indicate the ergonomically acceptable range (<15°).

Figure 3c: Relative frequency histograms showing lateroflexion in the cervical (Cspine LF) and thoracolumbar (TLspineLF) spine. Lateroflexion is categorized in neutral position (-5 to +5 degrees) and in slight lateroflexion (5 to 15 degrees), moderate lateroflexion (15 to 35 degrees) and large lateroflexion (higher than 35 degrees). The gray coloured columns indicate the ergonomically acceptable range (<15°).
Table 3 and figure 4 show 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).

Table 3: Mean head orientation in the sagittal plane

<table>
<thead>
<tr>
<th>HeadOSP</th>
<th>French</th>
<th>American</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-6.3±5.6</td>
<td>-6.3±5.6</td>
<td>0.465</td>
</tr>
</tbody>
</table>

Figure 4: Relative frequency histogram showing the orientation of the head (HeadOSP). The orientation angles are categorized in large flexion (-35 to -25 degrees), moderate flexion (-25 to -15 degrees), slight flexion (-15 to -5 degrees), neutral position (-5 to +5 degrees), slight extension (+5 to +15 degrees) and moderate extension (+15 to +25 degrees).
Discussion

Laparoscopic surgery provides well-established advantages for the patient, but the operating team is confronted with 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. The results of this study showed 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 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 degrees flexion to 5 degrees 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. 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 type 2 errors was the small sample size.

Limitations

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. 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.
Conclusion

In conclusion, this comparative ergonomic study indicates that there is no significant difference between operating posture of the vertebral column in the French and American position in a modern MIS suite.
References


