Surgeons' posture and muscle strain during laparoscopic and robotic surgery

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Postural muscle strain during laparoscopic or robotic surgery

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Keywords: Electromyography, Rapid Upper Limb Assessment, Musculoskeletal pain, Minimally invasive surgery, Robotic surgery.
ABSTRACT

**Background:** It is assumed that laparoscopic (LAP) and robotic-assisted laparoscopic surgery (RALS) differ in terms of the surgeon’s comfort. This study compared muscle workload, work posture, and perceived physical exertion of surgeons performing LAP or RALS.

**Methods:** Thirteen colorectal surgeons with experience in advanced LAP and RALS performed one of each operation. Bipolar surface electromyography was recorded from forearm, shoulder, and neck muscles, and expressed relative to EMG maximum (%EMGmax). The static, median, and peak level of muscle activity were calculated, and an Exposure Variation Analysis was conducted. Postural observations were carried out every ten minutes and ratings of perceived physical exertion before and after surgery were recorded.

**Results:** Performing LAP showed higher static, median, and peak forearm muscle activity compared with performing RALS. The left shoulder displayed the highest muscle activity in RALS at peak level. Exposure variation analysis demonstrated long-lasting periods of low-level intensity muscle activity for LAP in the shoulders, for RALS in the forearms, and for both in the neck. Postural observations found a higher demand for a change in work posture when performing LAP compared with RALS. Perceived physical exertion was not different between surgical modalities.

**Conclusions:** Minimally-invasive surgery requires long-term static muscle activity with a high physical workload for surgeons. RALS is less demanding on posture.
INTRODUCTION

It takes many years of education to become skilled for advanced surgical procedures and maintaining surgeon safety should be a priority. A high prevalence (20-100%) of musculoskeletal pain exists in surgeons\(^1,2\) and may be multi-site\(^3\). In addition to putative patient benefits\(^4,5\), robotic-assisted laparoscopic surgery (RALS) is thought to be less physically demanding for the surgeon than laparoscopic (LAP) surgery\(^6\). The highest muscle strain may be in the neck and shoulders for LAP but and lower back in RALS\(^7\) but others found it was the shoulders and forearm flexors that took the strain in RALS\(^8\). The objectives of the present study were to examine and compare concurrently measured muscular workload, work posture, and perceived physical exertion in surgeons performing LAP and RALS during surgical procedures.

METHODS

Study design

Thirteen colorectal surgeons from two different Danish hospitals participated. The surgeons were eligible if he/she was certified in both surgical modalities, had an almost equal distribution between performing LAP and RALS, and had a high weekly caseload. The surgeons gave written informed consent. The Danish Data Protection Agency approved the study (record number: 2015-57-0008). Approval from the regional ethics committee was sought but with the response that the present study was exempted. Measurements were conducted on-site during normal work procedures. Each surgeon performed two operations – one with LAP and one with RALS. Procedures were primarily performed as first cases, although for two surgeons the procedures were performed on the same day.
but with a sufficient break of > 2 hours to avoid muscle fatigue. Recording time was the actual operation excluding incision and closure.

**Measurements**

Before the first measurement day, a link to a questionnaire was sent to the surgeon by email. Briefly, the questionnaire collected information about 1) socio-demographics; 2) work experience; 3) prevalence and intensity of musculoskeletal pain; and 4) self-rated general health, physical capacity, workability, and productivity.

**Electromyography**

Bipolar surface electromyography (EMG) (Ag/AgCl, Ambu Blue Sensor, N-00-S/25, Denmark) was recorded continuously during surgery from four muscle groups (Fig. 1).

EMG-electrodes were positioned following European guidelines after standard cleaning of the skin. EMG electrodes were positioned underneath the usual operative clothing and measurements were transmitted wirelessly, thus not affecting the surgeons’ work or the hygiene of the operating room. The inter-electrode distance was 20 mm and resistance <20 kΩ. To express the EMG-activity relative to the surgeon’s maximum, the EMG signal recorded during surgery was normalized to isometric maximal voluntary contractions (MVC) and expressed as %EMG$_{\text{max}}$. For normalization of the
forearm extensor and flexor muscles, EMG was recorded during isometric handgrip performed with a hand dynamometer, standing upright, with the upper arm vertical, and a 90-degree bend at the elbow of the test arm, and without bending or extending the wrist. To ensure maximal activation of extensor carpi ulnaris, surgeons were also instructed to repeat the test in an ulnar deviated wrist position. For normalization of the trapezius muscle, EMG was recorded during isometric shoulder elevation performed in standing position with shoulders simultaneously elevated against a harness system that was fixed to the floor. For normalization of the neck extensors, EMG was recorded during isometric cervical extension against the surgeon’s hands folded behind the neck. For each normalization test, three isometric contractions were performed, separated by 20 s for recovery.

To compare \( \%\text{EMG}_{\text{max}} \) between surgical modalities and muscles, an amplitude probability distribution function (APDF) was conducted. The APDF extracts levels of static muscle activity (the 10% percentile, i.e., the level exceeded 90% of operation time), median muscle activity, and peak muscle activity (the 90% percentile, i.e., the level exceeded 10% of operation time). To explore the underlying variation in muscle activity, an exposure variation analysis (EVA) was conducted for each surgical modality and muscle group. The EVA analysis constitutes a matrix with accumulated elapsed time as the y-axis, amplitude levels (0-5; 5-10; 10-20; 20-30; >30 \( \%\text{EMG}_{\text{max}} \)) as the z-axis, and length of period at each amplitude level (0-1; 1-3; 3-7; 7-15; 15-31; 31-63; 63-127; 127-255; >255 seconds) as the x-axis.

**Postural observations**

Postural observations were carried out every 10 minutes, concurrent with EMG recordings using the
validated and reliable tool Rapid Upper Limb Assessment (RULA) \(^{16}\). The screening tool estimates total body strain by assigning a numerical rating of the posture of the upper limbs, and the neck, trunk, and legs. Further, a numerical rating of additional factors that strain the musculoskeletal system, i.e., repetitive action, static loading and force exertion is included. The ratings are scored accordingly using an algorithm to obtain a grand score ranging from 1 to 7, and an action level ranging from 1 to 4 (Table 1). Observations were recorded for the right and the left side of each surgeon. All observations were performed by author TD.

**Perceived physical exertion**

Perceived physical exertion (RPE) was registered using the 10-graded Borg Scale \(^{17}\). The RPE is subjectively reported by the surgeon and estimates the perceived physical stress and strain scored from 1-10. The score of ‘1’ indicates a lack of strain and ‘10’ indicates extremely uncomfortable and painful strain. Measurements were recorded before and just after surgery. All records were noted by author TD.

**Statistical analysis**

This study was based on a convenience sampling of surgeons being certified and experienced with both LAP and RALS. Sample size calculation on muscle activity level in different muscles estimated a sample of minimum 10 surgeons to detect a difference of 10\%EMG\(_{\text{max}}\) with a standard deviation of 10 and a power of 80\%.
Data analysis was conducted using Stata 15. Descriptive statistics were applied to describe surgeons’ characteristics. Data were normal distributed (Shapiro–Wilk test), thus a paired t-test was used to analyse for differences between LAP and RALS in EMG and RPE. Pearson chi-square test was conducted to test for differences between LAP and RALS in RULA. A \( p \leq 0.05 \) was considered statistically significant. Surgeon characteristics and RPE are reported as median(range), muscle activity is reported as group mean with 95% confidence interval, and RULA is reported as a percentage of total observations (%).

**RESULTS**

**Subject characteristics**

Twelve male surgeons and one female surgeon participated in this study. The median age was 49 (35-62) years, height 184 (175-191) cm, and body mass index 24(22-44) kg/m². Surgeons reported working 45 (40-70) hours per week. The number of performed operations as a leading surgeon per week was 2 (0-5) with LAP and 1 (0-2) with RALS. All surgeons had a minimum of 6 years of experience in minimally invasive surgery. Except for one surgeon, all surgeons had performed >100 LAP operations (one surgeon had performed 51-75 operations). Half of the surgeons had performed >100 RALS operations, four surgeons had performed between 51-100 operations, and three surgeons had performed <50 operations. The surgeons’ general health was as a minimum rated as ‘good’ and physical capacity was estimated above the level of people of the same age and gender for all three parameters (cardiorespiratory fitness, strength, and balance). Work ability and productivity were
rated 9(6-10) and 9(7-10), respectively, on a scale from 1-10 with ‘10’ being the best work ability/productivity.

**Musculoskeletal pain**

Table 2 presents the prevalence and intensity of pain. Neck and lower back were the most prevalent pain sites. On a numerical scale from 0 to 10, with ‘10’ being worst possible pain, median pain intensities during the past three months were 1.5(1-5) for the neck and 2.5(1-8) for the lower back. Pain in all body sites except for the elbows was reported as work-related, and none of the surgeons reported earlier injuries that may hinder the performance of surgery.

**Muscle activity**

Median recording time was not significantly different between LAP (85.3(58-317) minutes) and RALS (92.1(44-152) minutes). Table 3 presents the order and type of performed operations, patient’s body mass index, and recording time. There was no significant difference in patients’ body mass index between LAP and RALS.
Figure 2 demonstrates the static, median and peak level of muscle activity. Overall, the static level showed that the surgeons in 90% of the operation time had a muscle activity of 3%EMG_{max} or higher, independent of surgical modality. The median level was about 6-8%EMG_{max}, and the peak level was between 10-15%EMG_{max}, independent of surgical modality.

For the static level, a significant difference was present for the right forearm flexor muscle, with a muscle activity level of 3.85%EMG_{max} (95%CI: 2.34-5.36%EMG_{max}) in LAP compared with 2.32%EMG_{max} (95%CI: 1.69-2.95%EMG_{max}) in RALS. For the median and peak level, a significant difference was shown for all three right sided forearm muscles demonstrating highest muscle activity levels in LAP compared with RALS. For the peak level, muscle activity for the left upper trapezius was significantly higher in RALS (15.25%EMG_{max} 95%CI: 11.29-19.76%EMG_{max}) compared with LAP (10.70%EMG_{max} 95%CI: 9.60-17.92%EMG_{max}).

Additionally, for LAP but not for RALS, there was a significant difference between body sides, with significantly higher muscle activity in forearm and shoulder muscles for the right side compared with the left side.

Figures 3a and 3b depict the more complex EVA analysis illustrating the variability in muscle activity over time. Figure 3a presents results for the right forearm muscles. Performing LAP shows a variable muscle activity pattern varying between low and high intensities (0 to >30%EMG_{max}), and in periods of short duration (1-7 seconds). Performing RALS presents a muscle activity pattern within lower intensities (0-10%EMG_{max}, and 10-20%EMG_{max} for ulnaris) but for a longer duration.
(7-31 seconds). A similar pattern was shown for the left forearm muscles (Appendix 1a). Figure 3b shows the left trapezius muscle, indicating a shift in muscle activity pattern between the surgical modalities. For LAP, the muscle activity pattern is dominated by a static pattern with low intensities (mainly 0-10%EMG_{max}) that are sustained in extended periods. For RALS the periods are of shorter duration (1-15 seconds), and the intensities vary within a larger range of low and high intensities. The right trapezius muscle presented a similar pattern (Appendix 1b).

For the neck muscles, no visual difference was evident between LAP and RALS and revealed a pattern of low intensities (0-10%EMG_{max}), primarily with a duration of 31-63 seconds (Appendix 1b).

**Postural observations**

A total of 139 and 114 observations were obtained for RALS and LAP, respectively. Figure 4 illustrates the percentage distribution of the RULA grand scores according to each action level. None of the grand scores were deemed to action level 1: ‘Posture is acceptable if not maintained or repeated for long periods’. For LAP, half of the observations were deemed to action level 3: ‘Investigation and changes are required soon’. The rest of the observations were almost equally distributed among action level 2: ‘Further investigation needed, changes may be required’ and action level 4: ‘Investigation and changes are required immediately’. For RALS, none of the observations were deemed to action level 4 and almost all observations were deemed to action level 2, with only a small proportion deemed to action level 3. The distribution of the grand scores was significantly different between LAP and RALS for both right and left side ($p<0.001$).

The ratings of the upper extremities, and the neck, trunk, and legs were significantly different
between LAP and RALS (Figure 4 - table). For the right upper extremities, LAP showed a higher percentage of ratings distributed within higher grand scores compared with RALS ($p=0.001$). For the left upper extremities, RALS showed a higher percentage of ratings distributed within higher grand scores compared with LAP ($p=0.026$). For the neck, trunk, and legs, LAP ratings were distributed within higher grand scores compared with RALS ($p<0.001$).

**Perceived physical exertion**

Perceived physical exertion reported before the operation was not significantly different between LAP (1(0-3)) and RALS (1(0-2)) ($p=0.357$), nor were the ratings reported after the operation (LAP: 3(0-6) vs. RALS: 2(0.5-4)) ($p=0.835$).

**DISCUSSION**

Minimally-invasive surgery offers long-term static work postures, either standing or sitting, which induces a high physical workload for the surgeon. Both surgical modalities display a pattern of muscle activity level and duration that potentially may evoke muscle fatigue and pain but with a slight difference in the most exposed muscle groups. In addition to the modality specific muscle activation pattern, we observed a significant difference between surgical modalities in work posture. Performing LAP was associated with a higher number of observations deemed to action level three and four compared to performing RALS. This indicates that a change in work posture is needed soon or immediately when performing LAP. This difference was not reflected in the self-reported perceived physical exertion.
Measurement of the muscular workload across muscle groups and surgical modalities demonstrated a static muscle activity level of roughly 3%EMG_{max}, a median level of 6-8%EMG_{max}, and a peak level of 10-15%EMG_{max}. These levels are comparable to other occupations with a well-documented high prevalence of musculoskeletal pain, i.e., sewing-machine operators or helicopter pilots 18, 19. In the 1980s, Jonsson et al. proposed a threshold of acceptable muscular loading for continuous work of 2-5%EMG_{max} for static work 20. In our study, all muscles, independent of surgical modality exceeded the recommended 2%EMG_{max}. However, musculoskeletal pain is frequent even in jobs with a static level of 0.5-1%EMG_{max} 21, 22. Hence, it may be more likely, that the epochs of static work are the essential factor in relation to developing musculoskeletal pain 23. Likewise, prospective studies have shown a significant association between long-lasting epochs of low-level intensity and the development of musculoskeletal pain. These studies suggest that uninterrupted low-level activity periods lasting four minutes or longer should be avoided 24, 25. While the simple APDF analysis focuses mainly on the level of activity and does not account for the length of time in each level, the more complex EVA analysis includes the perspective of the combined intensity and duration of exposure. In the present study, the EVA analysis displayed that for the neck, 10% of total operation time was within low-level intensity and with a duration longer than four minutes for both LAP and RALS. This was also evident for the shoulders in LAP with 14% of total operation time.

The levels of activity measured by the APDF analysis display LAP to be more demanding for the forearm muscles, while RALS tends to be more demanding for the shoulders. However, when we incorporate the time perspective from the complex EVA analysis, the results show a general trend
with low-level intensities in long-lasting epochs in the shoulders for LAP and in the forearm muscles for RALS. A more varied work pattern may mitigate fatigue and pain development. Such a pattern with both low and high intensities of different duration was for LAP evident for the forearm muscles and RALS for the shoulders. The neck muscles revealed a similar activity pattern between LAP and RALS, indicating a less sustained static loading compared to forearm and shoulder muscles. This variation in muscle activity during surgery may be the essential factor in preventive and rehabilitating recommendations.

The seated position with arm and forehead support in RALS compared to the standing posture in LAP has been claimed to offer a more comfortable and less physically demanding work posture. Our study is the first to use RULA to assess work posture in a comparable study of real-life LAP and RALS procedures. Performing LAP was found to be significantly more physically demanding, which may be due to the improved condition for the neck, trunk, and legs in the seated work posture for RALS. The high scores among surgeons are similar to available RULA scores from other occupations known to have static and awkward work postures, i.e., dental hygienists and tattoo artists.

In a recent literature review on differences between LAP and RALS in muscle activation and physical workload, we found evidence of a small advantage for RALS. However, the studies varied regarding characteristics of the studied surgeons in gender, age, seniority, and experience as well as anthropometry, which are likely to influence the results and introduce differences in muscle activation and relative load between studies. Likewise, only four out of the included 15 studies were
conducted under real-life surgery settings, and the results simply may reflect the approximations of simulation rather than the complexity of the surgical theatre. Since the systematic review initiating the present study, at least three new studies on muscle activity have emerged in the literature. Dalsgaard et al. (2018) examined twelve gynaecological surgeons and reported LAP to be more physically demanding, based on higher perceived physical exertion as well as higher muscle activity in the forearm, neck, and shoulders compared with RALS. Armijo et al. (2018) reported, from 18 LAP operations and 10 RALS operations performed by 16 surgeons, significantly higher muscle activation in RALS for the shoulders, and lower muscle activation in the forearm muscles compared with LAP. González-Sanchez et al. (2017) examined one experienced surgeon during three long operations (>180 minutes) each with LAP and RALS. This study demonstrated no difference in muscle activity or muscle fatigue development, except for lower back showing a higher muscle activation during RALS compared with LAP. The study by Dalsgaard et al. (2018) had a higher percentage of female participants compared to our study. Females generally have a lower muscle strength compared with males and will, in a given task, have a higher relative activation to achieve the same absolute force as males. Likewise, earlier studies have emphasised that LAP instruments are developed for the male anthropometry which may increase the relative muscle activity of female surgeons. The higher percentage of female participants may, therefore, explain the consistent difference between LAP and RALS in this specific study.
Prior studies on possible alleviating effects of ergonomic initiatives in LAP and RALS have shown contradictive results. The lack of a significant effect of ergonomic improvements may be explained by a number of studies reporting that surgeons do not utilize the provided ergonomic possibilities, or are even unaware of good ergonomic work practice. Several studies also pinpoint that despite all the good initiatives, surgeons do not prioritize their comfort or consider future health consequences in the complex setting of the surgical theatre. A recent qualitative study with interviews of six surgeons about possible initiatives to alleviate the high rates of musculoskeletal pain in surgeons suggest a combination of more knowledge on the physical ergonomic possibilities, the use of micro-breaks during surgery, and specific strength training to increase their physical capacity. Likewise, the importance of the management prioritizing surgeons’ health was emphasized.

Performing micro-breaks during surgery has demonstrated a significant positive effect on musculoskeletal pain. Micro-breaks may interrupt the long-lasting epochs of low-level intensity, thereby enhancing the recovery of the metabolic changes in the muscle associated with muscle fatigue and musculoskeletal pain. However, depending on work schedule and caseload, muscles may need longer recovery time to regain force capacity. A recent randomized controlled trial examined the benefits of good ergonomic work practice and non-resistance stretching exercises before and after surgery. The intervention improved quality of life and reduced lower back pain. However, to increase the resilience of the surgeon and thereby reduce musculoskeletal pain in all affected body sites the provided exercises must be of high intensity (≥60% of one repetition maximum).
Berguer and colleagues demonstrated in the late 90s that 8-12% of the surveyed surgeons reported frequent pain in the neck and upper extremities when performing LAP. Today, 20 years later, rapid development in minimally invasive surgical techniques has emerged and the prevalence of pain is now more than six fold, with a majority of the surgeons experiencing multisite pain. In spite of patient benefits of the advanced technology, the ergonomic problems in minimally invasive surgery have not been solved and we are facing a negative development in surgeons’ musculoskeletal health. Likewise, previous studies have shown that muscle fatigue, pain, and disorders have adversely affected surgeons’ work ability, surgical performance, and surgeon career longevity. Thus, from a patient and societal perspective, it is pertinent to sustain surgeons’ work ability and ensure good musculoskeletal health. Improving surgeons’ knowledge of sound ergonomic work principles and increasing their physical capacity to minimize the relative load may be the most pressing agenda for surgeons’ future health and surgical career. It is acknowledged that the operation type might have different precision demands affecting muscular loading so the results may not be universally applicable.

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CONFLICTS OF INTEREST

For all authors, no conflicts of interest.
REFERENCES


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Body specific ratings (in percentage %) | Acceptable posture | Change may be needed | Change soon | Implement change
---|---|---|---|---
**LAP**
Upper extremities  
*Right side* | 0 | 50 | 48 | 2
*Left side* | 0 | 82 | 18 | 0
Neck, trunk, legs | 0 | 27 | 31 | 42

**RALS**
Upper extremities  
*Right side* | 0 | 73 | 26 | 1
*Left side* | 0 | 67 | 32 | 1
Neck, trunk, legs | 0 | 100 | 0 | 0
### Table 1: RULA grand scores, action levels and implications

<table>
<thead>
<tr>
<th>Grand Score</th>
<th>Action Level</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 or 2</td>
<td>1</td>
<td>Posture is acceptable if not maintained or repeated for long periods</td>
</tr>
<tr>
<td>3 or 4</td>
<td>2</td>
<td>Further investigation needed, changes may be required.</td>
</tr>
<tr>
<td>5 or 6</td>
<td>3</td>
<td>Investigation and changes are required soon</td>
</tr>
<tr>
<td>7+</td>
<td>4</td>
<td>Investigation and changes are required immediately</td>
</tr>
</tbody>
</table>
Table 2: The prevalence of musculoskeletal pain and pain intensity.

<table>
<thead>
<tr>
<th>Body region</th>
<th>Number of surgeons reporting pain</th>
<th>3 months pain intensity</th>
<th>7 days pain intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>8 surgeons (61.5%)</td>
<td>2.4(1-5)</td>
<td>2.4(0-6)</td>
</tr>
<tr>
<td>Right shoulder</td>
<td>4 surgeons (30.8%)</td>
<td>2.5(1-7)</td>
<td>2.0(0-6)</td>
</tr>
<tr>
<td>Left shoulder</td>
<td>2 surgeons (15.4%)</td>
<td>1.5(1-2)</td>
<td>1.0(0-2)</td>
</tr>
<tr>
<td>Right elbow</td>
<td>2 surgeons (15.4%)</td>
<td>5.0(2-8)</td>
<td>4.5(1-8)</td>
</tr>
<tr>
<td>Left elbow</td>
<td>1 surgeon (7.7%)</td>
<td>3.0*</td>
<td>3.0*</td>
</tr>
<tr>
<td>Right hands</td>
<td>2 surgeons (15.4%)</td>
<td>2.0^</td>
<td>1.0^</td>
</tr>
<tr>
<td>Left hands</td>
<td>3 surgeons (23.1%)</td>
<td>2.0(1-3)</td>
<td>2.0(0-2)</td>
</tr>
<tr>
<td>Upper back</td>
<td>3 surgeons (23.1%)</td>
<td>3.0(1-5)</td>
<td>3.0(1-3)</td>
</tr>
<tr>
<td>Lower back</td>
<td>8 surgeons (61.5%)</td>
<td>2.5(1-8)</td>
<td>2.5(0-7)</td>
</tr>
</tbody>
</table>

*: Only one surgeon reported pain in this body region. ^: no range reported. Pain intensity was rated on a scale from 0-10. Data are shown as median and range.
<table>
<thead>
<tr>
<th>Surgeon</th>
<th>First OP</th>
<th>LAP</th>
<th>RALS</th>
<th>Type of operation</th>
<th>Patient BMI (kg/m²)</th>
<th>Recording time (min.)</th>
<th>Type of operation</th>
<th>Patient BMI (kg/m²)</th>
<th>Recording time (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R0001</td>
<td>LAP</td>
<td>Colon sigmoid resection</td>
<td>29.0</td>
<td>112.6</td>
<td>Low anterior rectal resection with loop-ileostomy</td>
<td>29.0</td>
<td>316.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R0002</td>
<td>LAP</td>
<td>Right sided hemicolectomy</td>
<td>25.0</td>
<td>108.8</td>
<td>Left sided hemicolecotmy</td>
<td>26.0</td>
<td>135.7</td>
<td></td>
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<tr>
<td>R0003</td>
<td>LAP</td>
<td>Left sided hemicolecotmy</td>
<td>37.0</td>
<td>59.2</td>
<td>Right sided hemicolecotmy</td>
<td>23.0</td>
<td>86.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R0004</td>
<td>LAP</td>
<td>Intersphincteric abdominoperineal resection</td>
<td>26.0</td>
<td>132.7</td>
<td>Extended right sided hemicolecotmy</td>
<td>24.0</td>
<td>127.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R0005</td>
<td>LAP</td>
<td>Right sided hemicolecotmy</td>
<td>25.0</td>
<td>92.7</td>
<td>Colon sigmoid resection</td>
<td>25.0</td>
<td>99.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R0006</td>
<td>LAP</td>
<td>Rectal resection</td>
<td>21.8</td>
<td>61.3</td>
<td>Right sided hemicolecotmy</td>
<td>22.1</td>
<td>57.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R0007</td>
<td>LAP</td>
<td>Rectal resection</td>
<td>17.7</td>
<td>91.5</td>
<td>Rectal resection</td>
<td>23.3</td>
<td>85.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R0008</td>
<td>LAP</td>
<td>Colon sigmoid resection</td>
<td>23.8</td>
<td>100.9</td>
<td>Colon sigmoid resection</td>
<td>23.7</td>
<td>64.3</td>
<td></td>
<td></td>
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<tr>
<td>R0009</td>
<td>LAP</td>
<td>Colon sigmoid resection</td>
<td>23.5</td>
<td>46.8</td>
<td>Left sided hemicolecotmy</td>
<td>28.1</td>
<td>84.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R0010</td>
<td>LAP</td>
<td>Rectal resection</td>
<td>26.7</td>
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OP = operation. LAP = conventional laparoscopy. RALS = Robotic-assisted laparoscopic surgery.