REVIEW

Laparoscopic Vascular Surgery: A Systematic Review

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Objective. The objective of this systematic review is to evaluate the results of clinical studies on laparoscopic surgery for aorto-iliac disease.

Methods. A systematic review of the literature from 1966 to September 2006 on laparoscopic and robotic vascular surgery was performed. Only patient series containing more than 5 cases were included. Operative, clamping and anastomosis times, conversion, mortality and morbidity and hospital stay were evaluated.

Results. Thirty studies were identified. These were all descriptive and included 9 comparative studies. Operative times varied widely, the shortest being for hand-assisted procedures (2.5–4 hours) and the longest for totally laparoscopic procedures (4–6.5 hours). Clamping times were all <1 hour in hand-assisted procedures while in other techniques clamping times from 1–2.5 hours were seen. The conversion rate varied from <5% up to 16% in smaller series. The mortality rate was approximately 5% and frequently caused by cardiac ischemia. A variety of problems ranging from minor local wound problems to cardiopulmonary- and renal insufficiency, bleeding, ureter lesions and graft thrombosis were described. Mean hospital stay for nearly all procedures was <1 week.

Conclusions. Experience of laparoscopic surgery for aorto-iliac disease is still limited. Most study results are biased by patient selection. Only a few surgeons have mastered the required surgical technique and more data are needed to assess the clinical potential of this type of surgery, in comparison with the endovascular alternative. For wider implementation simplification of the surgical procedure seems necessary.

Keywords: Laparoscopy; Aorta; Arterial occlusive disease; Aneurysm; Minimally invasive surgical procedures.

Introduction

In 1993 Dion1 took the first step towards laparoscopic vascular surgery by performing a laparoscopic assisted aortobi-femoral bypass. Since then various endoscopic techniques and approaches have been developed to make laparoscopic treatment of occlusive and aneurysmal disease of the aorto-iliac vessels possible. At the same time, the number of endovascular options for treatment of aorto-iliac disease is still growing and the role of laparoscopic vascular surgery should be considered against the background of these ongoing developments.

Laparoscopic techniques include totally laparoscopic (both dissection and anastomosis carried out laparoscopically) as well as laparoscopic-assisted techniques involving hand-assisted laparoscopy (hand-assisted to facilitate the total procedure) and laparoscopic-assisted (laparoscopic dissection combined with a mini-laparotomy to perform a conventional vascular anastomosis). Recently, endoscopic surgery has seen the introduction of surgical robotic systems. In laparoscopic vascular procedures, these systems are mostly used to facilitate laparoscopic suturing of the anastomosis, and sometimes they are applied to the dissection of the aorta.2–6

The objective of this systematic review is to evaluate the results of clinical studies on laparoscopic and robotic surgery for aorto-iliac disease.

Methods

Literature search

A computer-assisted search was performed in the medical databases Medline (from January 1966 to
September 2006), Embase (from January 1988 to September 2006) and the Cochrane Database of Systematic Reviews, using the keywords “laparoscopy AND vascular surgery”. With the assistance of a clinical librarian an additional extensive search was performed using a combination of the following Medical Subject Heading (MeSH) terms: Surgery, Laparoscopy, Endoscopy, Vascular Surgical Procedures, Aorta, Abdominal, Renal Artery, Iliac Artery, Gastroepiploic Artery, Epigastric Arteries, Aortic Aneurysm, Abdominal, Iliac Aneurysm, Abdomen, Arteries, Aneurysm, Aortic Diseases, Arterial Occlusive Diseases. After identifying relevant titles, the abstracts of these studies were read to decide if the study was suitable. A manual search of reference lists of studies thus obtained was conducted for any relevant articles not found in the computerized search.

Criteria for inclusion

Clinical studies eligible for inclusion were those which described laparoscopic surgery performed for aorto-iliac disease. Case reports and small series ≤ 5 patients were excluded. Articles in languages other than English and German were excluded.

To be eligible articles had to describe original patient series. Studies containing duplicate material were excluded and the larger of the studies, containing the best documented data was included for analysis. Studies describing or evaluating the laparoscopic operative techniques without operative data were excluded. Data on operative, clamping and anastomosis times, hospital stay, mortality, complications and conversion were retrieved. Exclusion criteria were evaluated to identify which patient population would be suitable for laparoscopic surgery.

Study quality

Each article included was appraised by two reviewers using the critical review checklist of the Dutch Cochrane Centre7 (Table 1). This list evaluates the quality of the study by using the following key statements which in the form of questions can be answered with yes (+), no (−) and uncertain (?).

1. For a clear definition of study population the aneurysm size and TASC (TransAtlantic Inter-society Consensus) classification or equivalent description for both aneurysm repair and occlusive disease must be plainly stated.
2. Selection bias could only be sufficiently excluded if information on the complete cohort under treatment was stated.
3. A clear description of method of intervention was defined as one that stated numbers and types of operative procedure (e.g. bifurcation or tube grafts, uni- or bilateral bypasses).
4. A clear definition of outcomes and outcome assessment was defined as one that stated operative and hospital data numerically.
5. Independent assessment of data was acceptable only if independent or blinded observers had performed data collection and evaluation.
6. Duration of follow-up was considered to be adequate only if follow-up during the entire hospital stay up to discharge was complete.
7. Selective loss to follow-up was suspected if excluded or converted patients were not accounted for in the study.
8. Important confounders and prognostic factors excluding the issues addressed in statements 1 and 2 were, for instance, change of exclusion criteria resulting from increasing experience and the learning curve.

Furthermore, each study was evaluated using a list of detailed study characteristics as proposed by the Meta-Analysis of Observational Studies in Epidemiology (Moose) group.8 Studies were scored on 8 items. Each item was graded on a scale of 0 to 2 depending on the information available, so that the perfect study would have a maximum score of 16.

1. Consecutive series: 0 = not reported, 1 = not consecutive, 2 = consecutive.
2. Prospective series: 0 = not reported, 1 = retrospective, 2 = prospective.
3. Report on excluded patients: 0 = not reported, 1 = number only, 2 = number and reason of exclusion.
4. Surgical indications: 0 = not reported, 1 = general description like occlusive disease or aneurysm, 2 = details of extent of lesions (TASC) or aneurysm size.
5. Surgical procedures: 0 = not reported, 1 = total number only, 2 = number of each procedure. (e.g. bifurcation or tube graft)
6. Conversion: 0 = not reported, 1 = number only, 2 = number and reason of conversion.
7. Morbidity: 0 = not reported, 1 = number, 2 = number and specifications of complications.
8. Mortality: 0 = not reported, 1 = number, 2 = number and cause of death.

The authors had full access to the data and take responsibility for its integrity. All authors have read and agree to the manuscript as written.
Results

The initial search yielded 755 articles; 625 articles were excluded because they covered a topic other than laparoscopic surgery of the aorto-iliac tract. Ten papers were written in languages other than English or German (5 Czech, 3 French, 1 Italian, 1 Danish). Thirty-six experimental studies, comments, reviews, descriptions of complications and operative techniques were excluded.

Sixty-six potentially eligible articles remained, including 14 case reports and 6 small series. Two studies described laparoscopic re-intervention surgery after previous surgery and were excluded, as they were not considered standard procedures. Several authors were over-represented in the selected studies. Only the largest, most complete series were used, leading to a reduction of 14 articles.

In the remaining 30 articles, 8 hand-assisted (6 occlusive disease, 2 aneurysm), 6 laparoscopic assisted (3 occlusive disease, 3 aneurysm), 17 totally laparoscopic (11 occlusive disease and 6 aneurysm) and 2 robot-assisted series (1 occlusive disease and 1 aneurysm) were described.

The total reported number of operated patients was 1044, 630 for occlusive disease and 414 for aneurysm repair. Data from these studies, sorted according to operating technique and disease (occlusive disease/aneurysm) are shown in Tables 2 and 3.

Study Quality

All 30 selected studies were observational including 9 comparative studies (with contemporary series, historical controls, and endovascular repair). Because of the heterogeneity of the studies (varying types of operative technique and surgical procedure) pooling of data was not considered appropriate. Quality assessment of the studies (Table 1) showed two important deficits in most studies: inadequate description of the study population (mainly for occlusive disease) and a suspected selection bias of patients.
Table 2. Occlusive disease. Operative data of included studies

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>Total laparoscopic surgery</th>
<th>Laparoscopic-assisted surgery</th>
<th>Robot-assisted laparoscopic surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Operative time (minutes)</td>
<td>Operation time (minutes)</td>
<td>Hospital stay (days)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clamping time (minutes)</td>
<td>Anastomosis time (minutes)</td>
<td>Mortality x/n</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time (minutes)</td>
<td>Time (minutes)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>72</td>
<td>216+/-50*</td>
<td>57+/-21*</td>
<td>8(5–42)</td>
</tr>
<tr>
<td>2005</td>
<td>68</td>
<td>199+/-31*</td>
<td>85+/-32*</td>
<td>6.3+/-2*</td>
</tr>
<tr>
<td>2004</td>
<td>93</td>
<td>240(150–450)</td>
<td>60(30–120)</td>
<td>7(5–30)</td>
</tr>
<tr>
<td>2004</td>
<td>21</td>
<td>240(150–420)</td>
<td>60(30–120)</td>
<td>7(5–30)</td>
</tr>
<tr>
<td>2004</td>
<td>9</td>
<td>351(295–420)</td>
<td>128(75–170)</td>
<td>11(5–30)</td>
</tr>
<tr>
<td>2004</td>
<td>7</td>
<td>390(180–600)</td>
<td>59(45–110)</td>
<td>6(3–14)</td>
</tr>
<tr>
<td>2004</td>
<td>24</td>
<td>250(150–450)</td>
<td>70(55–120)</td>
<td>(3–25)</td>
</tr>
<tr>
<td>2005</td>
<td>8</td>
<td>405(260–589)</td>
<td>111(85–205)</td>
<td>8(3–57)</td>
</tr>
<tr>
<td>2004</td>
<td>58</td>
<td>238(140–420)</td>
<td>54(15–170)</td>
<td>8(3–32)</td>
</tr>
<tr>
<td>1997</td>
<td>9</td>
<td>160(90–240)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>45</td>
<td>208(155–300)</td>
<td>28(15–55)</td>
<td>6(3–26)</td>
</tr>
<tr>
<td>2003</td>
<td>33</td>
<td>230(150–270)</td>
<td>29(23–72)</td>
<td>6(4–42)</td>
</tr>
<tr>
<td>2003</td>
<td>35</td>
<td>180(120–290)</td>
<td>57(15–60)</td>
<td>7(4–15)</td>
</tr>
<tr>
<td>2002</td>
<td>18</td>
<td>191(160–221)</td>
<td>44(38–50)</td>
<td>7(5–9)</td>
</tr>
<tr>
<td>2002</td>
<td>8</td>
<td>234(170–319)</td>
<td>43(3–5)</td>
<td>4(1/8)</td>
</tr>
<tr>
<td>2000</td>
<td>29</td>
<td>149+/-35.2*</td>
<td>36.4+/-7.9*</td>
<td>4.5+/-2.2*</td>
</tr>
</tbody>
</table>

nr = not reported, t = tube repair, abf = aortobifemoral bypass, auf = aortounifemoral graft, if = ileofemoral graft, tea = endarterectomy.

* = mean and standard deviation.
+ = median and range.
\( \text{Clamping time (minutes)} = (57+/-13^*) \)

** e-s anastomosis 28(15–55); e-e anastomosis 69 (55–86).

\( \text{Hospital stay (days)} = 12.1+/-2.1^* \)
Table 3. Aneurysm repair. Operative data of included studies

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>Operative time (minutes)</th>
<th>Clamping time (minutes)</th>
<th>Anastomosis time (minutes)</th>
<th>Hospital stay (days)</th>
<th>Mortality x/n</th>
<th>Conversion x/n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total laparoscopic surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cau</td>
<td>2006</td>
<td>251 +/- 57*</td>
<td>101 +/- 15*</td>
<td></td>
<td>6(4-12)*</td>
<td>1/23</td>
<td>7/23</td>
</tr>
<tr>
<td>Coggia</td>
<td>2005</td>
<td>255(170-410)*</td>
<td>80(35-110)*</td>
<td></td>
<td>9(5-37)*</td>
<td>1/30</td>
<td>1/30</td>
</tr>
<tr>
<td>Coggia</td>
<td>2004</td>
<td>290(160-420)*</td>
<td>78(35-230)*</td>
<td></td>
<td>9(8-37)*</td>
<td>2/30</td>
<td>2/30</td>
</tr>
<tr>
<td>Kolvenbach</td>
<td>2004</td>
<td>227 +/- 34*</td>
<td>81 +/- 31*</td>
<td>53 +/- 9.0*</td>
<td>6.3 +/- 21.1*</td>
<td>6/37</td>
<td></td>
</tr>
<tr>
<td>Dion</td>
<td>2004</td>
<td>299 +/- 75*</td>
<td>109 +/- 52*</td>
<td>48 +/- 23*</td>
<td>6(3-32)*</td>
<td>0/7</td>
<td>1/7</td>
</tr>
<tr>
<td>Edoga</td>
<td>1998</td>
<td>391(180-600)*</td>
<td>146(6-286)*</td>
<td></td>
<td>6(2-25)*</td>
<td>2/22</td>
<td>2/22</td>
</tr>
<tr>
<td>Robot-assisted laparoscopic surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kolvenbach</td>
<td>2004</td>
<td>243 +/- 41*</td>
<td>96 +/- 22*</td>
<td>41 +/- 4*</td>
<td>7.3 +/- 2.4*</td>
<td>2/10</td>
<td></td>
</tr>
<tr>
<td>Laparoscopic-assisted surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Almi</td>
<td>2003</td>
<td>238(155-360)*</td>
<td>76(42-160)*</td>
<td></td>
<td>7(3-21)*</td>
<td>1/24</td>
<td>4/24</td>
</tr>
<tr>
<td>Castronuovo</td>
<td>2000</td>
<td>462(90-690)*</td>
<td>112(43-286)*</td>
<td></td>
<td>6(1-25)*</td>
<td>3/60</td>
<td>3/60</td>
</tr>
<tr>
<td>Kline</td>
<td>1998</td>
<td>246 +/- 55.2*</td>
<td></td>
<td></td>
<td>5.8 +/- 1.6*</td>
<td>0/20</td>
<td>2/20</td>
</tr>
<tr>
<td>Hand-assisted laparoscopic surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferrari</td>
<td>2006</td>
<td>257 +/- 70*</td>
<td>76 +/- 26*</td>
<td></td>
<td>4.4 +/- 1.7*</td>
<td>0/122</td>
<td>9/122</td>
</tr>
<tr>
<td>Kolvenbach</td>
<td>2001</td>
<td>181(130-345)*</td>
<td>57(44-90)*</td>
<td></td>
<td>6(4-21)*</td>
<td>1/29</td>
<td></td>
</tr>
</tbody>
</table>

### Conversion

In total, 78/1044 patients (7%) laparoscopy was converted to open surgery. The rate of conversion varied, with the highest number of conversions occurring in the smaller series. In series of >50 patients conversion rates were <5%, and in series of <20 patients up to 16%. In aneurysm repair the conversion rate was higher than in occlusive disease (39/630 vs 39/414). Reasons for conversion were: calcified aorta, bleeding from the cava, renal, or iliac veins or aorta, adhesions, the necessity of suprarenal clamping or inadequate exposure of the operative field due to collapse of the pneu-om-peritoneum or the pneu-mo-retroperitoneum or other technical difficulties. Self-imposed operative time limits (aortic cross-clamping time of more than 2 hours and total operative time of more than 4 hours) were sometimes a reason for conversion.2,55

### Clamping Time

Hand-assisted procedures had the shortest cross-clamping times, all <1 hour. Both laparoscopic-assisted and totally laparoscopic procedures reported clamping times varying from 54 to 146 minutes. Clamping times were a little shorter in operations for occlusive disease. Totally laparoscopic clamping...
times were at least 1.5 times longer than the comparative open series.\textsuperscript{21,26,37,61}

**Anastomosis Time**

Anastomosis time was reported only in some of the totally laparoscopic procedures and varied from 30–60 minutes for procedures without a robotic system and 41–74 minutes with a robotic system.

**Operative Time**

Operative time varied widely between both authors and laparoscopic techniques. Hand-assisted procedures had the shortest mean operative times, varying from approximately 2.5 to 4 hours. In laparoscopy-assisted techniques, both for aneurysm repair and occlusive disease, mean operative times of more than 4 hours were described, except for one study\textsuperscript{39} which reports less than 3 hours (occlusive disease).

In totally laparoscopic techniques the time varied from 4 to 6.5 hours. Operative times did not differ between aneurysm repair and occlusive disease. More recent studies report a shorter operative time than do the earlier studies.

The robot-assisted technique was used in 18 patients in 2 studies. Kolvenbach reports operating times (mean 4 hours) equal to those of total laparoscopic aneurysm repair without the use of a robotic system.\textsuperscript{2} The other study on occlusive disease reported very long (median 5.5 hours) operative times.\textsuperscript{6}

**Morbidity**

Reported complications included local wound problems (infection, seroma, dehiscence), respiratory and transient renal insufficiency, cardiac and mesenteric ischemia, splenic rupture, massive cholesterol embolization, graft thrombosis and bleeding. Five injuries of the ureter\textsuperscript{10,12,21,37,61} are mentioned. Limb graft thrombosis is reported 11 times.\textsuperscript{10,21,28,36,40,60,65,54,59} Six instances of anastomotic bleeding were reported.\textsuperscript{10,11,12,21,28,36}

**Mortality**

Reported mortality rates, in total 26/1044 (2\%) were in most series approximately 5\% or less. Mortality in aneurysm repair was slightly higher than in occlusive disease (11/414 vs 15/630). Mortality was mainly due to postoperative cardiac ischemic events, followed by mesenteric ischemia.

**Hospital Stay**

In all but six\textsuperscript{6,10,12,22,29,26} reports, mean hospital stay was one week or less, varying from 3 to 11 days, for both the total laparoscopic approach and the laparoscopic and hand-assisted approach regardless of the surgical procedure.

**Discussion**

This systematic review shows that since the introduction of laparoscopic surgery in 1993, only a small number of clinical studies on laparoscopic aorto-iliac surgery have been published. A variety of laparoscopic techniques, approaches and operative procedures were used and most studies were of an observational character and contained a limited number of patients. In addition we assumed a considerable selection bias in all series as the publications do not adequately describe the characteristics of the whole cohort of consecutive patients under treatment. This limits the full evaluation of laparoscopic surgery in relation to open or endovascular techniques.

In contrast to revolutionary changes in other fields of surgery, laparoscopic surgery has not become the minimal invasive alternative for the traditional xiphopubic incision in aorto-iliac surgery. The technical challenges presented by this advanced laparoscopic procedure probably preclude its wide implementation. Most surgeons start with relatively simple laparoscopic procedures for aorto-iliac occlusive disease. Operative procedures vary, but the majority of reported cases are aorto-bifemoral bypasses. Operative times are long, but for this particular patient population it seems a safe (acceptable mortality/morbidity) and feasible (few conversions) procedure. As expected mid-term patencies of laparoscopic aorto-bifemoral bypasses\textsuperscript{32,41} suggest results identical to those of open surgery. Over the years aorto-bifurcation bypasses with their good and durable patency rates have been the gold standard for treatment of TASC C and D lesions.\textsuperscript{69} However, nowadays multilevel occlusive disease is also being treated by recanalization and percutaneous transluminal angioplasty/stenting. Early results show that patency rates (one year primary assisted patency rate 88\%) of these procedures are inferior to those of surgical bypass and re-intervention is frequently necessary.\textsuperscript{70} However, percutaneous treatment remains a less invasive treatment option with fewer complications. If endovascular options are failing and alternative surgery is considered, laparoscopic aortobifemoral bypass might be a minimal invasive alternative.
Few series have been published on laparoscopic aneurysm repair. These studies report longer operative times and higher conversion rates compared to laparoscopic surgery for occlusive disease, although mortality is comparable with open procedures. Laparoscopic aneurysm repair appears to be more difficult than bypass surgery and is only done by a few surgeons. This is in contrast to the wide implementation of endovascular repair of aortic aneurysms. This is a minimally invasive technique with a low mortality and is relatively easy to master. Taking this into consideration the results of laparoscopic aneurysm repair do not yet justify its broader implementation.

Long operative times are a major point of concern of laparoscopic surgery. As in most other fields of surgery, laparoscopic operative time is generally longer than its open counterpart, although current results are probably biased by the inevitable learning curve of this recently introduced technique. The question arises if every vascular surgeon should learn advanced laparoscopic procedures and indeed if these procedures are applicable to every patient. Their safety and feasibility have been demonstrated, but only in series of selected patients operated by dedicated surgeons.

The benefits of laparoscopic aorto-iliac surgery are found in the combination of its minimally invasive character (reduction of hospital stay and post-operative pain, earlier return to daily routines) and the durable results of conventional open surgery (less necessity for continuous follow-up). However, the technique needs to become less demanding in order to make wider implementation possible. Technical difficulties of the vascular anastomosis need to be addressed e.g. by the development of a vascular stapler. The long learning curve can probably be shortened by extensive training in laparoscopic suturing before embarking upon patient procedures. The hand-assisted technique might further reduce the complexity of the procedure.

Conversion rates are difficult to interpret, because they are also influenced by other factors than the surgeons experience, e.g. patient selection, self-imposed operative time limits and surgical technique. However, the higher rate of conversion in small series is probably affected by a learning curve.

Only few centers have used robotic systems for laparoscopic aortoiliac surgery. The use of robotic systems has not yet reduced operative time in the few available series. Most studies had selection criteria for including patients for a laparoscopic technique, which sometimes changed with growing experience. More research is required to identify which patients are suitable candidates for laparoscopic surgery and to establish its additional value as the minimal invasive alternative to endovascular treatment.

Although a few dedicated centers are able to offer laparoscopic vascular surgery routinely,26,54 it is too early to draw conclusions from the data currently available on the potential of this technique in order to justify its wider implementation.

In conclusion, laparoscopic aorto-iliac surgery is still in its infancy and is only practised in a few dedicated centers. Although safe and feasible, operative time is still long. The observational, non-comparative character and selection bias of most published series are their major limitations. More data are required to define the value of laparoscopic vascular surgery in comparison with endovascular and open surgery.

References


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