Aortic surgery and laparoscopy: still a future in the endovascular surgery era?

Ann. Ital. Chir., 2017 88, 2: 97-104
pii: S0003469X17025866

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Laparoscopic surgery (LS) is the minimally invasive alternative to open surgery and endovascular approach for treating major aortic diseases. Only few reports in the literature describe the long-term outcomes of the laparoscopic approach for major vascular diseases. Furthermore, the widespread use of endovascular techniques has limited the use of LS to well-selected patients. This review evaluated the results of LS for aortic disease and compared the clinical outcomes of laparoscopic technique with those of open and endovascular surgery. A systematic review was performed by using the MEDLINE database, along with a meta-analysis of the reported studies on the treatment of abdominal aortic aneurysm (AAA) and/or aorto-iliac occlusive disease (AIOD). Forty-three studies were analyzed (17 for AAA and 26 for AIOD), with a total of 1197 patients with AAA and 1307 patients with AIOD. Laparoscopic surgery, when performed in experienced centers, is a feasible and safe technique for the treatment of AAA and AIOD in patients unfit for open and endovascular repair. Assisted laparoscopic approach has shown better outcomes than totally laparoscopic repair, with a lower rate of mortality and morbidity. Endovascular repair, however, remains the gold standard in the treatment of AAA.

KEY WORDS: Abdominal aortic aneurysm, Aorta, Aneurysm, Aorto-iliac occlusive disease, Endovascular aneurysm repair, EVAR, Laparoscopy, Endovascular, Repair, Laparoscopic Assisted, Laparoscopy Vascular, Laparoscopic surgery, Totally

Introduction

Aortic diseases may be treated by using open, endovascular and laparoscopic techniques. The perioperative mortality rates in open and endovascular repairs range from 4.3% to 15% and from 0.9% to 2.5%, respectively [1,2]. Open repair has been the standard of care for the treatment of abdominal aortic aneurysm (AAA) and aorto-iliac occlusive disease (AIOD) for over 40 years[3]. However, the open technique is associated with higher morbidity, mortality, and complication rates, with longer stay in hospital and intensive care unit [4]. The endovascular approach has currently replaced open repair as the most adopted treatment of AAA and AIOD, owing to its well-documented benefits such as reduced perioperative mortality and morbidity rates, and hospitalization duration [5,6]. However, endovascular aneurysm repair (EVAR) may result in a higher number of reinterventions during follow-up and may be not always suitable because of severe aorto-iliac disease or hostile proximal neck, small diameter, and severe tortuosity of the iliac artery [7-9]. Laparoscopic surgery has been proposed as an alternative approach for the treatment of AAA. After the first description from Dion in 1993 [10], different approaches have been developed to treat AAA and AIOD, such as total laparoscopic (transperitoneal or

Pervenuto in Redazione Maggio 2016. Accettato Luglio 2016
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retroperitoneal) and assisted techniques (hand- and robot-assisted approaches)[11-13]. The laparoscopic technique has the advantage of being a minimally invasive alternative to open repair, without the need for frequent follow-up. Indeed, it could be a valid approach for the treatment of aortic disease for patients unfit for open and endovascular treatment, but it requires an extensive experience in both vascular and laparoscopic surgery and should be performed only in highly experienced centers. The aim of this review is to assess the indications and clinical outcomes of elective laparoscopic treatment of AAA and AIOD by a comparison between open and endovascular procedures.

Material and Methods

An extensive search for original articles that focused on abdominal aortic aneurysm and aorto-iliac occlusive disease in Medline and PubMed published between 1998 and 2015 was conducted. The search terms used were "laparoscopic technique," "abdominal aortic aneurysm," "aorto-iliac obstructive disease," "aortic disease," "assisted-laparoscopic," "totally laparoscopic," "minimally invasive," and "vascular laparoscopic surgery." All the papers identified were English-language full text papers, and a search of the reference lists of selected articles for more studies was made. Two groups were identified as follows: patients who underwent laparoscopic repair (LR) of AAA (group A) and those who underwent LR for AIOD (group B). The articles excluded were as follows: case reports, those that reported less than 10 laparoscopic cases, reviews, those that included patients with ruptured aneurysms, those that did not report a 30-day follow-up, and those describing aortic diseases other than AAA or AOID. Demographic characteristics (number of patients, age, sex, and comorbidities), type of aortic disease (aneurysm diameter, infra-renal or juxta-renal, aor-

Table I - *Total laparoscopic technique for IAAA and JAAA*

Author	Year	Patients (n)	Age (years, mean)	30-day mortality (%)	Operative time (min)	Clamp-time (min)	Complication rate (%)	Reintervention rate (%)	Conversion rate (%)	ICU stay (days)	Hospital stay (days)
IAAA											
Ludemann and Swanstrom[16]	1999	6	NA	NA	NA	NA	NA	NA	33.3	NA	10
Edoga *et al* [15]	1998	22	72.2	0.8	391	146	NA	NA	9	2.5	6.5
Cau *et al* [20]	2006	23	68	4	251	101	22	4	30.4	1	6.4
Coggia *et al* [21]	2005	49	73	3	290	81.5	18	8	6.1	1	10
Javerliat *et al* [22]	2013	99	68	0	210	81	17	5	5	2	6
Kolvenbach *et al* [23]	2006	131	NA	3	265	95	18	6	18	NA	5
JAAA											
Di Centa *et al* [29]	2009	32	70	3	270	83	59	3	6	48	10
Coggia *et al* [30]	2008	13	70	0	260	77	NA	NA	0	NA	NA

Legend: IAAA: infrarenal abdominal aortic aneurysm; JAAA: juxtarenal abdominal aortic aneurysm; NA: not available

Table II - *Assisted laparoscopic technique for IAAA and JAAA*

Author	Year	Patients (n)	Age (years, mean)	30-day mortality (%)	Operative time (min)	Clamp-time (min)	Complication rate (%)	Reintervention rate (%)	Conversion rate (%)	ICU stay (days)	Hospital stay (days)
IAAA											
Cardon *et al* [19]	2005	33	NA	0.5	148	66	NA	NA	NA	NA	NA
De Donato *et al* [17]	2003	80	80	0.5	167	NA	NA	NA	0	NA	3.5
Alimi *et al* [24]	2003	24	70.9	7	195	NA	0	14	7.1	1	4
Castronuovo *et al* [25]	2000	60	70.6	5	462	112	13	3	5	2	6
Ferrari *et al* [31]	2009	188	69	0	231	25	12	2	0	14	4
Kline *et al* [26]	1998	20	70.9	0	245.6	NA	20	5	10	2	6
Kolvenbach *et al* [23]	2006	215	NA	2	175	55	7	4	5.1	2	7
Veroux *et al* [18]	2010	50	61.2	0	179	NA	8	4	NA	NA	4.2
Howard *et al* [28]	2014	37	NA	2.7	NA	NA	NA	NA	NA	NA	NA
Coscas *et al* [27]	2014	31	80	3.2	289	NA	3.2	NA	NA	NA	NA
JAAA											
Ferrari *et al* [31]	2009	83	71.7	0	220	28	17	0	0	14.7	4.2

Legend: IAAA: infrarenal abdominal aortic aneurysm; JAAA: juxtarenal abdominal aortic aneurysm; NA: not available

to-iliac stenosis, or obstruction) were analyzed. The perioperative outcomes analyzed in both groups were 30-day mortality, intensive care unit (ICU) and hospital stay, complications, and reinterventions within 30 days after surgical repair. The technical outcomes analyzed were aortic cross-clamping time, procedural time, and rate of conversion to open repair. Furthermore, the graft patency and reinterventions during the follow-up period were analyzed.

We identified 2647 articles, of which 1289 included patients that belong to group A. Of the articles identified, 1195 were excluded based on the title; 41, because of incomplete data; 25, after reading the full text; and 11, because they presented data already reported in other studies. Seventeen studies were concerning laparoscopic treatment of infrarenal (IAAA) [15-28] and juxtarenal abdominal aortic aneurysm (JAAA) [29-31], and were found to be eligible for this review (Tables I, II). In group B, 1358 articles were reviewed, of which 1232 were excluded based on the title; 24, because they reported comments, experimental studies, reviews, and operative techniques; and 76, because they presented case reports or data already reported in other studies. Twenty-six articles were, therefore, included in the final analysis [20,32-56] (Tables III, IV).

Owing to the heterogeneity of the reported data, all the variables were analyzed as mean values and a direct comparison was not always possible.

Group A included 1197 patients with AAA [15-31], of whom 1069 (89.3%) had an IAAA, whereas 128 patients (10.7%) had a JAAA. Total laparoscopic technique (tLT) was performed in 330 patients (30.8%) with IAAA and

TABLE III - *Total laparoscopic technique for AIOD*

Author	Year	Patients (n)	Age (years, mean)	30-day mortality (%)	Operative time (min)	Clamp-time (min)	Complication rate (%)	Reintervention rate (%)	Conversion rate (%)	Hospital stay (days)
Fourneau *et al* [55]	2010	139	57.1	2.2	250	59	10.1	3.6	13.7	5.8
Di Centa *et al* [36]	2008	150	NA	2.7	260	81	20.4	NA	0.3	7
Tiek *et al* [34]	2012	14	54.9	0	273	48	0	NA	0	4.5
Ghammad *et al* [33]	2015	173	57.2	2.4	205	50	6,9	15	12.1	7
Fukui *et al* [35]	2012	32	NA	0	338	73	30	NA	15.6	NA
Kazmi *et al* [32]	2015	50	62	10	265	59.5	20	NA	14	5
Bruls *et al* [56]	2012	95	61	0	242	62	NA	NA	20	8.1
Qi *et al* [54]	2014	12	59.5	8.3	560	76	41	NA	25	NA
Cau *et al* [20]	2006	72	NA	0	216	57	NA	NA	2.7	8
Dooner *et al* [39]	2006	13	NA	0	390	NA	NA	NA	2.7	7
Rouers *et al* [40]	2005	30	NA	0	244	66	NA	NA	20	5
Lin *et al* [42]	2005	68	NA	1.4	199	85	NA	NA	4.4	6.3
Olinde *et al* [41]	2005	22	NA	4.5	267	90	NA	NA	9	4
Coggia *et al* [43]	2004	93	NA	4.3	240	68	NA	NA	4.3	7
Remy *et al* [45]	2005	21	NA	0	240	60	NA	NA	4.7	7
Dion *et al* [44]	2004	49	NA	1.9	290	99	NA	NA	9.8	5
Barbera *et al* [46]	1998	24	NA	0	250	70	NA	NA	16.6	NA

Legend: AIOD: aorto-iliac occlusive disease; NA: not available

TABLE IV - *Assisted laparoscopic technique for AIOD*

Author	Year	Patients (n)	Age (years, mean)	30-day mortality (%)	Operative time (min)	Clamp-time (min)	Complication rate (%)	Reintervention rate (%)	Conversion rate (%)	Hospital stay (days)
Fourneau *et al* [38]	2006	18	57.4	5.5	207	NA	11	5.5	0	7.5
Klem *et al* [37]	2006	33	59	0	307	35.3	24	NA	9	9
Fourneau *et al* [49]	2005	46	NA	4.5	208	28	19.5	NA	2.1	6
Debing *et al* [44]	2003	13	NA	0	230	29	NA	NA	7.6	6
Wijtenburg *et al* [45]	2003	25	NA	4	180	37	NA	NA	8	7
Silva *et al* [52]	2002	18	NA	0	191	44	33.3	NA	5.5	7
Kolvenbach *et al* [53]	2000	29	NA	3.4	149	36.4	NA	NA	NA	4.3
Alimi *et al* [47]	2004	58	NA	3.4	238	54	NA	NA	1.7	7
Lacroix *et al* [48]	1999	10	NA	NA	350	NA	NA	NA	NA	4

in 45 patients (35.1%) with JAAA. Assisted laparoscopic repair was performed in 739 patients with IAAA (69.2%) and in 83 patients with JAAA (64.9%). Meanwhile, group B included 1307 patients with AIOD [20,32-56], of whom 1057 (80.9%) received a total laparoscopic repair and 250 underwent an assisted laparoscopic repair.

Results

Perioperative and Technical Outcomes in Patients with AAA (Group A)

In the total laparoscopic cases (n = 330), the 30-day mortality rate was 2.5%. The mean time of hospital stay was 7.75 ± 2.6 days. The mean time of intensive care unit (ICU) stay was 1.3 ± 0.6 days. The mean cross-clamping and operative times were 105.7 ± 28.1 min and 281.4 ± 67.8 min, respectively. The rate of conversion to open repair was 10.6%. The complication and reintervention rates were 18.7% and 5.7%, respectively. The main causes of reintervention were as follows: postoperative bleeding, splenic rupture, colonic ischemia, compartment syndrome, hematoma, hernia, iliac dissection, peripheral ischemia and limb thrombosis, bowel perforation, and obstruction.

In the laparoscopic-assisted cases (n = 739), the 30-day mortality rate was 2.3%. The mean time of hospitalization was 5.4 ± 1.3 days, and the mean time of ICU stay was 4.2 ± 5.5 days. The mean cross-clamping and operative times were 64.5 ± 36.1 min and 230.7 ±103.4 min, respectively. The rate of conversion to open repair was 3.7%. The reintervention rate was 5.3%. The main reasons for reintervention were as follows: limb and colonic ischemia, graft thrombosis, postoperative bleeding, ureteric injury, bowel obstruction, and laparocele repair.

Only two studies reported the outcomes of patients with JAAA treated with tLT, with a total of 45 patients [29,30], with 30-day mortality rates of 0%[30] and 3%, respectively [29]. In the interesting study by Di Centa *et al* [29], the median time of hospital and ICU stay were 48 days (range, 12–552 days) and 10 days (range, 4–37 days), respectively. The mean cross-clamping and operative times were 80 ± 4.2 min and 265 ± 7.1 min, respectively. The rates of conversion to open repair and reintervention were respectively 0%[30], and 6%[29] and 3%[(29)], and only one patient required a reintervention for intestinal obstruction [29].

Ferrari *et al* [31] reported the results of assisted laparoscopic treatment in 45 patients with JAAA. The 30-day mortality was 0%, while the mean durations of hospitalization and ICU stay were 4.2 ± 1.5 and 14.7 ± 16 days, respectively. The mean cross-clamping and operative times were 28 ± 6 min and 220 ± 66 min, respectively. The rates of conversion to open repair and reintervention were both 0% for both studies.

The data on long-term follow-up of patients treated with the laparoscopic technique are limited. In recent series of patients treated with tLT with a follow-up extending up to 42 months, no aneurysm-related mortality was reported [20-22,27], with a need for reintervention of 2% [22]. In the patients treated with assisted laparoscopic repair with a follow-up extending up to 38 months [18,24,31], no aneurysm-related mortality and reinterventions were reported. In the tLT of JAAA, no aneurysm-related mortality and need for reintervention were reported at a follow-up of 38 months [27,31], while one case of reintervention for iliac pseudoaneurysm was reported in the assisted laparoscopy group [31].

In summary, laparoscopic repair of abdominal aortic aneurysm is a safe technique with long-term results comparable with those of open surgery. Total laparoscopic repair requires longer cross-clamping and operative times than assisted laparoscopic repair, with higher rates of conversion and incidence of postoperative complications. These techniques require a high-level expertise in both vascular and laparoscopic surgery, and should be performed only in specialized centers. Owing to its longer operative time and higher postoperative complication rate, the assisted laparoscopic technique should be preferred to tLT for AAA repair.

Perioperative and Technical Outcomes in Patients with AIOD (Group B)

The total number of reported cases was 1307 [20,32-56]. Of the patients, 1057 underwent tLT and 250 underwent assisted laparoscopic technique. In the 1057 patients who underwent a total laparoscopic surgery for AIOD [20,31-36,39-46,55-56], the 30-day mortality rate was 2.2%. The mean hospital stay was 6.2 ± 1.3 days. The mean cross-clamping and operative times were 69.6 ± 14.6 min and 278.2 ± 86.2 min, respectively. The conversion rate to open repair was 5%, whereas the complications rate was 18.3%. The main complications were as follows: 2 cases of massive bleedings and 1 case each of inferior mesenteric artery injury, graft embolism, graft rupture, groin infection, and residual aortic stenosis.

In the 250 patients treated with an assisted laparoscopic technique [37,38,47-53], the 30-day mortality rate was 2.3% and the mean hospital stay was 6.4 ± 1.6 days. The mean cross-clamping and operative times were 38 ± 9.7 min and 223 ± 60.3 min, respectively. Of the 250 patients, 4.8% required conversion to open repair. The complication rate was of 21.9%. The main complications after the intervention were as follows: respiratory disease, wound dehiscence, sepsis, bypass occlusion, and incisional hernia[37,38,49,52].

Only eight studies [32,33,35,36,38,49,55,56] reported mid- and long-term follow-up periods. Fourneau *et al* [55] reported

a reintervention rate of 3.6% at the 40-month follow-up, while Ghammad *et al.* [33] reported a 15% of reintervention rate during a 60-month follow-up. The 1-year primary patency was 92% [35], and the 3-year primary patency rates were 87% [33], 93%[35], and 97% [36], with no reported AIOD-related mortality or reintervention.
Furthermore, Fourneau *et al* [49] reported a 1-year primary patency of 97.5% in 46 patients with AIOD treated with a hand-assisted laparoscopic technique. In another study of Fourneau *et al* [38], the 1-year assisted primary patency and reintervention rate were 96.6% and 5.5%, respectively.
In summary, laparoscopic aorto-iliac reconstruction may be considered a valid minimally invasive alternative to open surgery in selected patients, with good mid-term results.

Discussion

Comparison With Open Repair

The main advantages of laparoscopic technique are the less postoperative pain and shorter hospital stay than those associated with open repair [57]. This is more evident in the assisted laparoscopic approach [57]. Meanwhile, the laparoscopic approach is affected by a longer cross-clamping and operative times.
This review showed that tLR and aLR have similar mortality rate, hospital stay duration, and ICU stay duration, although operative and cross-clamping times were shorter for aLR than for tLR, but significantly longer than open repair. This could reflect in the longer ICU stay of tLR patients. The laparoscopic technique requires a long learning curve, so that many studies reported in their initial experience a high rate of conversion to open repair of up to 30% [14] and an increase in operative time of more than 4 h [14,21]. According to Coggia *et al* [21], surgical skills improve significantly after 50 cases of laparoscopic aortic disease repair; hence, laparoscopic techniques should be performed only by surgeons with high expertise[58].
This review suggests that laparoscopic repair of major abdominal diseases may be performed safely with satisfactory short- and mid-term results. The laparoscopic technique may reduce postoperative pain and respiratory distress compared with open repair [58], with a similar in-hospital mortality, and durations of hospital and ICU stay[57]. Laparoscopic techniques have the advantages of reduced duration of ileus, shorter return to ambulation, and reduced postoperative doses of narcotics [57]. Laparoscopic surgery has been reported to have better outcomes than open repair, probably due to the higher incidence of laparotomy-related complications in open surgery, occurring in up to 25% of cases[59]. On the other hand, laparoscopic surgery has a longer cross-clamping and operative times than open repair, with an increased risk of perioperative cardiovascular complications. Furthermore, laparoscopic surgery should be performed in selected patients and in well-experienced centers. Laparoscopic aortobifemoral bypass has similar results as open surgery, with comparable mid-term patency rates [60,61].

Comparison With Endovascular Repair

Currently, laparoscopic surgery has been significantly replaced by endovascular surgery, which allows treatment of many complex aorto-iliac diseases, without the need for a "surgical" approach. The benefits and safety of endovascular repair has been well documented and reported in several trials and meta-analysis [2,62]. Endovascular aneurysm repair (EVAR) has become the treatment of choice in 70-100% of patients [2], with a significantly reduced 30-day mortality rate (2.5%) as compared with that of laparoscopic technique (15%), even in emergency settings [2]. On the other hand, endovascular repair is associated with higher rates of reintervention and graft-related complications such as the endoleaks [62,63,64]. Moreover, the major concerns of endovascular repair are the long-term patency of the stents and the need for life-long imaging surveillance [63,65]. Given the better results of EVAR, elective laparoscopic repair should be reserved only for patients not suitable for endovascular repair, such as patients with hostile aortic necks, severe aorto-iliac disease, or severe angulation and stenosis of iliac arteries [7-9], as suggested by Coscas *et al* [66], who reserved the use of laparoscopic technique for high-risk patients with unfavorable anatomies.
Late complications of EVAR may limit the use of endovascular procedures in favor of laparoscopic techniques, but the recent introduction of stent grafts, chimney, periscope techniques, and fenestrated grafts has significantly improved the outcomes of endovascular repair of AAA [66]. Laparoscopic techniques could be useful for treating type Ia [5] or II [67] endoleaks after EVAR, by ligation of the inferior mesenteric and lumbar arteries. When the endoleak is sustained by the inferior mesenteric artery, laparoscopy is more often successful, but a high rate of technical failure with a recurrence rate of 20–80% has been reported [68].
When compared with endovascular procedures, laparoscopy faces the limitations of longer cross-clamping time of the aorta and operative time, with more blood loss and need for transfusion, and prolonged ICU stay [4]. Moreover, the learning curve for laparoscopy is significantly longer than that for endovascular techniques [4]. Endovascular treatment is less invasive, with significantly lower morbidity and mortality. Thus, laparoscopy should be only considered as an alternative, minimally invasive treatment modality for patients not suitable for EVAR.

Conclusion

Laparoscopic surgery for the treatment of AAA or AIOD has proved to be safe and efficacious in selected patients, with morbidity and mortality rates similar to those in open surgery. However, it requires a high level of expertise and a long learning curve, and should be performed only in highly experienced centers. Endovascular procedures have progressively and rapidly replaced open and/or laparoscopic surgery in the treatment of AAA and AIOD because of their less invasiveness and better outcomes. In patients unsuitable to undergo endovascular surgery, laparoscopy could be considered, in experienced centers, as a minimally invasive alternative to open repair.

Acknowledgments

The authors thank Editage by Cactus for editing the manuscript for English Language

Riassunto

La chirurgia laparoscopica è l'alternativa mini-invasiva alla chirurgia tradizionale e al trattamento endovascolare della patologie aortiche. Solo pochi lavori in letteratura descrivono i risultati a lungo termine della chirurgia laparoscopia per il trattamento della patologie aotiche maggiori. In questa review della letteratura sono stati valutati il risultati della chirurgia laparoscopica dell'aorta confrontandone i risultati con la chirurgia tradizionale e la chirurgia endovascolare. È stata effettuata una ricerca sistematica utilizzando il database MEDLINE insieme ad una meta-analisi degli studi pubblicati sul trattamento degli aneurismi dell'aorta addominale e della patologia aortica ostruttiva. Quarantatre studi sono stati valutati per un totale di 1197 pazienti con aneurisma dell'aorta addominale e 1307 con patologia ostruttiva dell'aorta. La chirurgia laparoscopica, se eseguita in centri con considerevole esperienza, è una alternative valida e sicura per il trattamento delle patologie aortiche maggiori per i pazienti non suscettibili di trattamento chirurgico tradizionale o endovascolare. Il trattamento laparoscopico assistito ha risultati migliori rispetto alla tecnica laparoscopica pura, con un più basso tasso di mortalità e morbilità. La chirurgia endovascolare, tuttavia, rimane il gold standard per il trattamento della patologia aneurismatica aortica.

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