Laparoscopic-assisted treatment of abdominal aortic aneurysm requiring suprarenal cross-clamping

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Objective: **Hand-assisted laparoscopic surgery (HALS) was previously employed to treat patients with infrarenal abdominal aortic aneurysm (IAAA). The use of HALS for juxtarenal abdominal aortic aneurysm (JAAA) has never been validated. In this study, we report our experience with this technique to demonstrate its feasibility and prove its safety in dealing with JAAA.**

Methods: **From October 2000 to October 2008, we have selectively treated 271 patients with abdominal aortic aneurysm with the HALS technique. Of these, 83 were JAAAs which required a suprarenal aortic clamping (group A), and 188 were IAAA (group B). General data of the two groups were analyzed for comparability purposes and operative and postoperative data were prospectively collected. Additionally, patients in group A were stratified in three classes according to their pre-existing degree of renal function impairment. Statistical significance was defined at the $P < .05$ level.**

Results: **Mean operative time was 220 minutes ± 66 in group A and 231 minutes ± 64 in group B ($P > .05$). The mean duration of suprarenal clamping was 28 minutes ± 6; whereas infrarenal clamping lasted an average of 25 minutes ± 5 ($P > .05$). Mean intraoperative blood loss was 1023 ± 584 mL for group A and 961 ± 633 mL for group B ($P > .05$). No conversion or 30-day postoperative mortality was recorded in either group. Sixteen percent of the patients in group A developed a postoperative complication, vs 11% in group B ($P > .05$). Mean postoperative stay for group A and B was 4.2 ± 1.5 and 4.2 ± 1.9 days, respectively ($P > .05$). Postoperative kidney function significantly worsened in 5 patients in group A (6%). A prolonged warm ischemia time (>40), pre-existing renal dysfunction, and diabetes, correlated to the development of postoperative renal insufficiency. Follow-up of patients averaged 37.9 ± 20 months. The incidence of incisional hernias in group A and B was 15.5% vs 11.1%, respectively ($P > .05$).**

Conclusion: **The HALS technique proved to be feasible and safe not only for patients with IAAA, but also for the management of patients with JAAA. No significant difference could be shown in the comparison between the two groups, apart from the expected higher rate of postoperative renal dysfunction after suprarenal clamping. In view of the demonstrated benefit of this minimally invasive approach, we believe that it should be included among the alternative options of treatment for these patients. (J Vasc Surg 2009;50:1006-11.)**

Over the past 5 years, the number of elective open surgical repairs for abdominal aortic aneurysm (AAA) progressively decreased in favor of endovascular aneurysm repair (EVAR) exclusion, which is now the treatment of choice in about half of the patients.[1-4] Minimally invasive surgery, in dedicated centers, plays an intermediate role between the open approach and EVAR.[5,6] Pure laparoscopy or laparoscopic-assisted techniques were introduced to improve the perioperative outcome of open surgery by reducing the trauma of access, obviating at the same time the drawbacks and long-term sequelae of EVAR.[5-11] Still, the shortage of comparative data makes any objective evaluation of the various available techniques uneasy, and selection of patients to one treatment or the other often reflects local expertise or the availability of a given technology, rather than established indications. The recent introduction of fenestrated endoprostheses has further complicated this picture, providing a new endovascular option also for AAA with necks shorter than 1 cm, the so-called juxtarenal abdominal aortic aneurysm (JAAA).[12] Although this type of aneurysm is still considered a good indication to open surgery by most vascular surgeons,[3] nonetheless promising results have also been reported with the endovascular repair of JAAA.[13,14]

Hand-assisted laparoscopic surgery (HALS) has been shown to be of value in the treatment of selected patients in general surgery,[15] urology,[16] and vascular surgery.[17] With HALS, the surgeon has the capability to regain tactile feedback and finger dissection and to retract and expose tissues with the nondominant hand as in open surgery, still retaining most of the benefit of pure laparoscopic surgery. The potential of this approach in the treatment of AAA has already been reported by our group and others.[8,18] However, the technical challenge posed by JAAA makes all laparoscopic options less likely to be successful in dealing with a short aneurysmal neck and suprarenal cross-clamping.

The purpose of this study was to prove the feasibility and assess the value of HALS as a surgical option to treat JAAA in need of suprarenal aortic cross-clamping. Prospective data were collected from patients undergoing elective HALS treatment of JAAA and compared to those with

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Fig. Operative setting for the HALS technique.

infrarenal abdominal aortic aneurysm (IAAA) still operated on by the same technique.

Our data was further analyzed in view of the results reported in the medical literature with two other minimally invasive treatments of JAAA: pure laparoscopy and fenestrated endografting.

MATERIALS AND METHODS

From October 2000 to October 2008, 972 patients with AAA were treated in election at the Division of Vascular Surgery of the University of Pisa, using a conventional open approach in 132 patients (13.6%), EVAR in 208 (21.4%), a left retroperitoneal approach in 163 (16.7%), a minilaparotomic technique in 198 (20.4%), and with the HALS technique in 271 (27.8%).

In 83 patients of this last subgroup (36.6%), a suprarenal aortic cross-clamping was employed due to the presence of a short neck in 75 patients (90.4%) defined as a distance between the origin of the aneurysm and the renal artery shorter than 1 cm, or to manage an aortic neck of poor quality, mechanically unsuitable for infrarenal cross-clamping as in 8 patients (9.6%). The mean length of the aortic neck in these patients was 4.6 ± 2 mm. These 83 patients formed group A of this study, whereas group B consisted of the remaining 188 patients, in whom the HALS technique was still adopted, but without suprarenal aortic cross-clamping. The mean length of the aortic neck in group B was 26.3 ± 8 mm.

Table I. Comparison of general data of patients in group A (suprarenal aortic cross-clamping) vs patients in group B (infrarenal aortic cross-clamping)

Variable	*Group A*	*Group B*	P *value*
Number of patients	83	188	
Mean age	71 ± 7	69 ± 7	.922
Percentage of males	98%	97%	.904
Mean size of AAA (cm)	5.7	5.5	.859
ASA status 1 & 2	40.4%	37.2%	.715
ASA status 3 & 4	69.6%	62.8%	.329

AAA, Abdominal aortic aneurysm; *ASA,* American Society of Anesthesiology.

Table II. Comparison of associated morbid conditions of patients in group A (suprarenal aortic cross-clamping) vs patients in group B (infrarenal aortic cross-clamping)

	Group A	*Group B*	P *value*
Number of patients	83	188	
Hypertension	69.3%	51.7%	< .05
Ischemic cardiac disease*	37.1%	26.9%	.413
COPD	27.4%	30.7%	.689
Hyperlipidemia	25.8%	22.4%	.716
Obesity (BMI >30)	14.5%	14.7%	.930
Diabetes	4.8%	5.7%	.604
Renal dysfunction (creatinine ≥1.25 mg/dL)	16.8%	8.3%	< .05

COPD, Chronic obstructive pulmonary disease; *BMI,* body mass index.
Chronic obstructive pulmonary disease diagnosed after static and dynamic evaluation of respiratory function.
*Ischemic cardiac disease: previous myocardial infarction, previous myocardial revascularization (bypass or stent), myocardial ischemia under medical treatment.

Our technique for the HALS treatment of IAAA has already been described.[18] In case of JAAA, after blunt finger dissection of the aortic neck, a special self-retracting system was applied to displace the left renal vein upwards and facilitate both vision and clamp positioning above the renal arteries (Fig). The remaining phases of the procedure are similar to what was already described for the HALS approach in patients with IAAA.[18]

General data and associated morbidity of patients in the two groups are depicted in Tables I and II, respectively. Patients in group A had a higher incidence of hypertension and impaired renal function, but the existence of no statistical difference for most of the indicated variables makes the two groups comparable. We have further divided 14 patients in group A (16.8%) with impaired renal function (creatinine >1.25 mg/dL) in three classes:[19,20]

Class a: mild dysfunction (creatinine between 1.25-1.5 mg/dL): 5 patients;
Class b: moderate dysfunction (creatinine between 1.5-2 mg/dL): 6 patients;
Class c: severe dysfunction (creatinine >2 mg/dL): 3 patients.

A bifurcated aortic graft was implanted in 22 patients (26.5%) in group A to treat a concomitant iliac aneurysm

and in 47 patients (25%) in group B; in 3 patients in group A (3.6%) and 2 in group B (1%) an aorto-bifemoral bypass was performed to manage an occlusive disease of the iliac arteries. In all the other patients, repair of the aneurysm was achieved with an aorto-aortic graft. An autologous blood recovery system was routinely employed, and blood transfusions were given when needed. Postoperative analgesia with continuous intravenous infusion of morphine was used in all patients for the first 8 hours after surgery; additional shots of ketorolac were given upon request and recorded.

Operative time, blood loss, and duration of aortic cross-clamping were prospectively recorded for both groups, together with the following outcome measures:

- Operative (30-day) mortality;
- Time spent in the intensive care unit (ICU);
- Occurrence and type of complication;
- Time for resumption of a solid diet;
- Need for parenteral support defined as more than 500 mL of fluid infusion/day;
- Need for additional postoperative analgesia;
- Hospital stay.

Serum creatinine was checked postoperatively at 12 hours, 24 hours, 48 hours, 72 hours, 96 hours, and at discharge. Renal postoperative dysfunction was defined as an increase in the serum creatinine greater than 20% of the preoperative baseline.[19] Patients with transient or permanently impaired kidney function and those who demanded the use of hemofiltration/hemodialysis were recorded.

The follow-up was conducted with a physical exam, blood tests, and ultrasound scan studies at 6 months, 1 year, and yearly thereafter. All analyzed data were prospectively collected in a computerized database. Descriptive statistics are given as mean ± SD or range, as appropriate, whereas comparisons between the differences in the two groups were made using the *t* test for independent samples and the Mann-Whitney test, as appropriate. Statistical significance was defined at the $P < .05$ level.

RESULTS

Mean operative time was 220 ± 66 minutes in group A (JAAA patients) and 231 ± 64 minutes in group B (IAAA patients) ($P > .05$). An average of 49 ± 22 minutes were needed to complete the aorto-iliac laparoscopic dissection before a suprarenal cross-clamping, compared to 53 ± 26 minutes for the dissection of patients in group B ($P > .05$). The mean duration of suprarenal cross-clamping was 28 ± 6 minutes; whereas infrarenal cross-clamping lasted on average 25 ± 5 minutes ($P > .05$). Bilateral lower limb reperfusion occurred after an average of 69 ± 22 minutes in group A and 72 ± 24 minutes in group B ($P > .05$). In no case was the left renal vein interrupted during the dissection, and an intraoperative cold renal perfusion was never used.

Mean intraoperative blood loss was 1023 ± 584 mL for group A and 961 ± 633 mL for group B ($P > .05$). Thanks to the cell saver, only 16.8% of the patients in group A and 5.4% in group B required blood transfusions for an average of 2.7 and 2.4 units, respectively. Conversion to open surgery during the laparoscopic preparation of the aorta was never required; in 3 patients in group A (3.6%) and in 11 patients in group B (5.8%), the HALS access incision was extended caudally to reach the external iliac arteries for the anastomosis for an additional length of 3 cm, so that the total length of the wound was 10 cm. A small POLAR renal artery was reimplanted in 2 patients in group A (2.4%) and in 1 patient in group B (0.5%). All patients were extubated immediately after surgery on the operative table. No 30-day postoperative mortality was recorded in either group. The average ICU stay in group A was 14.7 ± 16 hours and 14.4 ± 25 hours for group B ($P > .05$). A total of 16.8% of the patients in group A developed a postoperative complication vs 11.7% in group B, as detailed in Table III. No significant difference could be found in the overall rate of morbidity or in the separate analysis of the incidence of each complication. A solid diet could always be given to all patients of both groups on the first postoperative day. Fluid parenteral support was maintained up to 39.7 ± 13 hours for patients in group A vs 39.4 ± 17 for those in group B ($P > .05$). A total of 3.6% of the patients in group A and 5.3% of the patients in group B required medication to relieve postoperative pain in addition to the scheduled treatment ($P > .05$). Mean postoperative stay for group A and B was 4.2 ± 1.5 and 4.2 ± 1.9 days, respectively ($P > .05$).

Table III. Comparison of postoperative complications of patients in group A (suprarenal aortic cross-clamping) vs patients in group B (infrarenal aortic cross-clamping)

	Group A	*Group B*	P *value*
Number of patients	83	188	
Arrhythmia	5 (6.0%)	6 (3.1%)	.715
Myocardial infarction	1 (1.2%)	2 (1.0%)	.999
Pneumonia	2 (2.4%)	5 (2.6%)	.904
Renal dysfunction*	5 (6.0%)	2 (1.0%)	.543
Postoperative bleeding	1 (1.2%)	3 (1.5%)	.986
Graft thrombosis	0	1 (0.5%)	.904
Prolonged ileus	0	3 (1.5)%	.808
Overall incidence of postop complications	16.8%	11.7%	.541

*Creatinine increasing up to 20% of preoperative value.

Serum creatinine of all the patients in group A increased during the first 48 hours after surgery, reaching a mean peak of 9% of the baseline value. Return to preoperative values occurred after an average of 72 hours. Postoperative kidney function significantly worsened (serum creatinine >20% of the preoperative level) in 5 patients of group A (6%), 3 belonging to class c (severe dysfunction), and 2 to class b (moderate dysfunction). In these patients, serum creatinine returned to baseline during postoperative day 4. In patients with preoperative renal insufficiency (all classes), the incidence of renal dysfunction was 21.4% vs 2.8% in patients with a normal renal function. No patient in group A required hemodialysis or hemofiltration despite the suprarenal cross-clamping.

One patient in group B developed a mild renal dysfunction (0.5%) that completely recovered 3 days after surgery.

A relationship was identified between the length of the warm ischemia time and postoperative renal dysfunction. For a clamping time shorter than 30 minutes (79.5% of cases) we encountered only one case of postoperative impaired renal function (1.5%). When the suprarenal clamping time lasted between 30 and 40 minutes, which occurred in 20.5% of our cases, we observed the development of postoperative renal dysfunction in 4 patients. These 4 patients also had associated preoperative renal insufficiency (2 in class a, and 2 in class b). Therefore, this pre-existing condition in our series carried a 25% risk to develop postoperative renal dysfunction. Also, 1 out of 4 patients with diabetes in group A developed a transient increase of creatinine.

Follow-up of patients averaged 37.9 ± 20 months. Midterm mortality was 1 out of 83 (1.2%) and was related to lung cancer. Renal function deteriorated (>20% compared with the value of discharge) in only 1 patient in group A (1.2%), without evidence of renal artery stenosis (this patient had normal preoperative and discharge renal function, suprarenal clamping time was 38 minutes). An iliac pseudo aneurysm in a patient in group A was detected and treated by exclusion with a covered stent. Midterm mortality for patients in group B was of 3 patients out of 188 (1.5%), related to colon and lung cancer in 1 patient each, and to myocardial infarction in the remaining patient. Two patients (1%) developed infrainguinal noncritical limb ischemia, and 1 patient presented with unilateral renal artery stenosis without renal function impairment or critical hypertension. All implanted grafts were patent. The incidence of incisional hernia in group A and B was 15.5% vs 11.1%, respectively ($P > .05$).

DISCUSSION

In a previous report, we have shown the potential benefit and value of HALS to treat a selective group of patients with AAAs.[18] Briefly, the operative technique consists of a preliminary laparoscopic dissection of the aorta, which is accomplished under video-endoscopic guidance thanks to a 30° oblique viewing laparoscope. One additional 5 mm Trocar (Karl Storz Endoscope, Tuttlingen, Germany) is placed in the left flank and gives access to a dissecting scissor, whereas exposure and retraction is provided by the nondominant hand of the operating surgeon, introduced through the HALS access device placed inside a midline laparotomy of the length of about 7 cm. Then the subsequent phases of aortic cross-clamping and graft interposition are done with an open approach through the same minilaparotomy after having set in place a self-retaining retractor (Fig) and with the aid of long dedicated needle holders.

Juxtarenal aneurysms pose an additional technical challenge to the vascular surgeon even in the setting of open surgery, and for this reason we initially decided to exclude from the HALS approach patients in need of a suprarenal cross-clamping. However, after a pilot series of 20 patients with IAAAs, we realized that with the exposure of the aneurysmal neck, what we could achieve with the HALS technique was excellent and also the time needed to control back-bleeding from the collaterals inside the aneurysm and perform the proximal graft anastomosis was comparable to that of the open approach. We therefore started to offer the HALS option also to patients with juxtarenal aneurysms and to collect the prospective data that forms the body of this study. Because we have included all of our early cases in this report, our data might have been affected by the so called "learning curve", favoring the results of the juxtarenal aneurysms whose treatment with the HALS technique was introduced only after the first 20 infrarenal cases. However, looking more in detail to the results of those early 20 patients compared to the subsequent series of infrarenal HALS aneurysms, it seems that the only appreciable – but not statistically significant – difference was in the length of the laparoscopic dissection, with no significant difference in the other outcome measures. Moreover, considering the first 50 cases, 15 were already juxtarenal aneurysms requiring a suprarenal clamping.

The two considered groups of patients proved comparable having no significant difference in the analyzed variables (Tables I and II), except for a higher incidence of hypertension and mild renal dysfunction in patients of group A. Analysis of the results of HALS in the two groups of patients showed no significant difference in operative time, duration of aortic cross-clamping, blood loss, ICU stay, resumption of a solid diet, need for parenteral fluid support, postoperative analgesia requirement, and finally length of hospital stay. This data provides evidence that the HALS approach is not only feasible in patients with JAAA, but also safe, with an outcome similar to that of patients with IAAA. Time spent in the ICU and postoperative stays in our patients were even shorter than those reported by Sarac et al[21] in patients undergoing conventional open surgery. It should be noted that there is currently a cultural resistance on the part of the patient and his/her family in our communities to accept a reduction of the hospital discharge below the threshold of 4 days, which is indeed frequently perceived as too short in view of the severity of the underlying disease. The blood loss related to the HALS technique was still higher in comparison to that of the full open and mini-incisional approach.[5,11] The higher proportion of patients requiring blood transfusions in group A, despite a substantially equivalent intraoperative blood loss, can be explained by the relative anemic state of patients with nephropathy that was compensated intraoperatively.

Although the intraoperative use of a blood recovery system significantly reduces the need for transfusion, the development of new devices for a faster control of back-bleeding aortic collaterals would represent a desirable technical evolution to limit the amount of blood loss of the current minimally invasive techniques.

To date, a pure laparoscopic technique to treat patients with suprarenal aneurysm has been reported only by Coggia et al.[22] The potential advantage of his approach is the capability to perform a two-stage aortic cross-clamping:

firstly infrarenal, to open the aneurysmal sac and control back-flow from the aortic collaterals, then suprarenal to perform the proximal graft anastomosis. In this way, the time of renal ischemia is limited to the performance of the suture between the aorta and the graft. With the HALS approach, this two-stage aortic cross-clamping is not feasible due to the limited exposure of the aneurysmal neck area, once the pneumoperitoneum has been desufflated and the procedure turns into a minilaparotomy. Although we tried the technique on a few occasions, the switching between clamps with a limited view of the aortic neck proved to be technically very demanding and hazardous, so that we no longer use it. Although the time of suprarenal cross-clamping reported by Coggia was shorter than ours (24 minutes), 4 out of his 13 patients developed a transient renal failure (30%), which compares favorably with the 6% incidence of this complication in our series, as low as 0.5% in case of IAAA. The much shorter duration of the pneumoperitoneum of the HALS technique, in comparison with the pure laparoscopic approach, might account for this difference. Indeed, a prolonged pneumoperitoneum is known to reduce kidney perfusion[23] and experimental evidence has also been provided to support the physiopathology of this side-effect of laparoscopy.[24] Nonetheless, the well known benefit of the minimally invasive techniques, be these pure laparoscopy of HALS,[8-10] that include a quicker recovery time, less postoperative pain, earlier return to a normal diet, reduced infection rate, and shorter hospital stay, might also have, in combination, a protective effect on renal function.

The mini-incisional technique, first reported by Cerveira et al[5] and Turnipseed et al,[11] has never been employed, to the best of our knowledge, to treat JAAAs. The HALS approach conversely represents a hybrid technique in that the initial dissection is accomplished with the help of the pneumoperitoneum. This is a considerable aid in dissecting the high neck of a juxtarenal aneurysm, when compared to the full mini-incisional approach and accounts for the lack of reports of JAAA managed with the latter technique. We also believe that using HALS, by offering a direct – transperitoneal – approach to the abdominal aorta and a mini-incisional open repair, results in a less technically demanding procedure than the pure laparoscopic approach, still providing the patient most of the benefits of the totally laparoscopic technique.

We believe that these should be regarded as *absolute* contraindications to the HALS technique: all emergencies, redo aortic surgery, massive calcified walls at the clamping or anastomotic sites, and concomitant aneurysms of the hypogastric arteries. *Relative* contraindications are: previous major abdominal surgery, and patients with severe respiratory disease that might not tolerate the 12 mm Hg positive pressure of CO_2 pneumoperitoneum of the HALS technique. In all of the above circumstances, our choice would be in favor of the conventional open technique. In our practice, the choice between the various available treatments (EVAR, HALS, minilaparotomy, or open surgery) is taken collegially during the weekly case discussion by all the surgeons of the unit. The EVAR treatment is reserved to patients with the appropriate anatomical features, or in the presence of high risk for other approaches. The decision between HALS and minilaparotomy is today mainly dependant on the availability of surgeons with sufficient experience with laparoscopy, rather than on the patient's related factors. At present, half of our vascular surgeons have been fully trained in this technique; additionally, two other surgeons from other hospitals have been trained in Pisa, Italy, and are running independent programs of HALS aortic surgery.

The recent application of endovascular therapy also for JAAA has the potential to further reduce the trauma of access to these patients. However, a 16% incidence of periprocedural renal dysfunction was reported after EVAR in patients with a previously normal renal function and as high as 39% in those with pre-existing renal insufficiency.[25] Nonetheless, it should be considered that current candidates for fenestrated endografting are only patients excluded from open surgery in view of their high risk, which are, therefore, not comparable to those undergoing HALS repair in the present series.

Midterm results in patients in group A did not show any significant worsening of the renal function and only 1 patient out of 83 required additional surgery for a graft-related complication. The high rate of incisional hernia at the HALS access site in both groups still represents an open problem with this technique.

In conclusion, our study provides evidence that the HALS technique can be safely adopted also for the treatment of patients with JAAA with an outcome similar to that of patients with IAAA. The video-endoscopic preparation of the suprarenal aortic segment is easier than expected with an excellent visual control of this area. This technique does not increase the risk of postoperative or midterm renal damage or the incidence of other major complications.

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AUTHOR CONTRIBUTIONS

Conception and design: MF, DA, AP
Analysis and interpretation: MF, DA, AP
Data collection: DA, RB, ADC
Writing the article: MF, DA, AP
Critical revision of the article: MF, AP
Final approval of the article: MF, DA, RB, ADC, AP
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