

In situ Laser Fenestration of Visceral Endografts (InLoVE): Midterm Outcomes from a Multicentre Study

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WHAT THIS PAPER ADDS

This paper analyses the midterm outcomes of *in situ* laser fenestration (ISLF) in emergency paravisceral and thoraco-abdominal aneurysms. Data represent a heterogeneous real world patient cohort across three specialised aortic centres with a high proportion of acute cases (79%). This work substantially contributes to the limited body of evidence regarding acute visceral ISLF. The results show a midterm survival of 72%, freedom from target vessel instability of 89%, and 100% assisted primary patency, which demonstrates promising results for this technique.

Objective: Emergency complex abdominal aortic diseases are challenging to treat. During *in situ* laser fenestration (ISLF), aortic branches are covered and flow is restored by *in situ* fenestration of the stent graft, with promising midterm results. This study aimed to expand on the limited body of knowledge of midterm outcomes of ISLF in renovisceral aortic pathology in a multicentre setting.

Methods: Retrospective pooled data on consecutive ISLF cases of visceral aortic stent grafts undertaken between 2018 – 2023 in three aortic centres were analysed. Technical success was defined as successful vascularisation with a bridging stent graft and acceptable final angiographic images without signs of endoleak related to the bridging stent graft. Target vessel instability was defined as an endoleak related to the bridging stent graft, disconnection, kink, stenosis, occlusion of bridging stent, re-intervention to the bridging stent graft, or rupture or death related to the bridging stent graft.

Results: Sixtyfive ISLFs were performed in 34 patients, with a mean age 74 years. The procedure was acute in 79%, and 35% were ruptures. Pre-stenting was performed on 56 target vessels (86%). Four patients (12%) died within 30 days; all presented with a rupture. Technical success was achieved in 61 of 65 (94%) ISLFs. All failed cannulations were in the renal arteries: three due to difficult angulations and one dissected during cannulation. Median follow up was 16 (interquartile range 5, 22) months. Cumulative survival at six months, one, and two years was 88%, 81%, and 72%, respectively. Six (10%) target vessel instabilities were detected: two (3%) type III endoleaks and four (7%) stent stenosis; all of which required re-lining. Freedom from target vessel instability at six months until the end of follow up was 89%. On the latest follow up scan, all successfully deployed ISLF bridging stents were patent (primary assisted patency 100%; 61 of 61) without signs of type III endoleak.

Conclusion: ISLF is a promising tool for emergency endovascular procedures in complex anatomies.

Keywords: Endovascular aortic repair, *In situ*, Laser fenestration, Paravisceral aortic aneurysm, Thoraco-abdominal aneurysm

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INTRODUCTION

Patients with emergency aortic disease involving the renovisceral arteries are challenging to treat. Open procedures

are often not feasible in this high risk cohort and correlate with increased peri-operative risk compared with endovascular solutions.^{1,2} Different endovascular solutions such

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as off the shelf (OTS) devices (Cook T-branch, Artivion E-nside), physician modified endovascular grafts (PMEGs), and the chimney technique (ChEVAR), have been developed for these situations when standard endovascular aortic repair (EVAR) is anatomically not possible. However, a complex often prolonged modification time in PMEGs, the risk of endoleak in ChEVAR,^{3,4} and anatomical restrictions and increased aortic coverage⁵ for OTS devices limit their use. Custom made devices (CMDs) are frequently deployed in elective settings with good results^{6,7} but a manufacturing period of 4 – 12 weeks renders them unsuitable for the emergency setting.

In situ laser fenestration (ISLF) of aortic stent grafts is a technique where circulation to aortic branch vessels is secured by fenestrating the stent graft fabric with a laser probe after deployment into the aorta. Some centres have reported their experience with ISLF in the visceral aorta in emergency and elective settings with promising results.^{8–11} Leger *et al.*¹⁰ reported 48 of 50 successful fenestrations in a series of 20 cases, and Dean *et al.*⁹ reported successful fenestrations in 26 of 27 cases. Le Houérou *et al.*⁸ presented two year midterm results of a series of 44 procedures (108 fenestrations) of complex abdominal aortic aneurysms (AAAs) unsuitable for a custom stent graft or open surgery; technical success was 97%, two year overall survival was 73%, and aortic and bridging stent related re-intervention free survival was 70% and 90.6%, respectively. While the experimental data^{12,13} and short term results are promising, experience remains limited and questions regarding durability remain unanswered.¹⁴ This study aimed to expand on the limited body of knowledge regarding midterm outcomes of ISLF in renovisceral aortic pathology in a multicentre setting.

MATERIALS AND METHODS

A retrospective review was undertaken of pooled data of all consecutive ISLF cases of visceral aortic stent grafts performed between May 2018 and May 2023 in the university hospitals in Uppsala, Malmö, and Copenhagen. Ethics approval for the retrospective review was granted in each unit.

The ISLF cases performed during the period were identified in each centre's local databases. In addition, the total number of complex aortic cases performed during the period was recorded and split into CMDs (F-EVAR, B-EVAR, hybrid F/B-EVAR), OTS devices, PMEGs, chimneys, and open surgery.

A minimum of one ISLF for either the coeliac, superior mesenteric, or renal artery was required for inclusion, and any type of emergency aortic disease was included. ISLF was the method of choice in the authors' centres when there was no suitable OTS device available and the patient was deemed unfit for open repair. All cases underwent a pre-operative 1 mm multislice computed tomography (CT) scan for detailed anatomical evaluation, including centreline measurements. All procedures were performed in hybrid angiographic suites with peroperative fusion imaging under

general anaesthesia. Femoral access was obtained, with a percutaneous technique preferred. After heparinisation, the target vessels in the visceral segment were often presented for visualisation, with stents positioned at the ostia of the vessels. The aortic main body was then deployed covering all target vessels. A steerable sheath was positioned within the aortic stent graft and the position of the steerable sheath was confirmed with two orthogonal views before the laser fenestration was performed with a Turbo Elite (Philips Healthcare, Amsterdam, the Netherlands) laser catheter (0.9 – 2.3 mm). A 0.014" or 0.018" wire was passed through the laser fenestration into the target vessel. Pre-dilatation was performed using a plain angioplasty balloon (4 – 6 mm) followed by deployment of a balloon expandable covered stent to bridge from the stent graft main body to the target vessel stent. Flaring was performed as per the surgeon's discretion. See [Figure 1](#) for a detailed description of the ISLF process.

Technical success was defined as successful vascularisation of the ISLF target vessel with a bridging stent graft and an acceptable final angiogram without signs of endoleak related to the bridging stent graft. Stroke, spinal cord ischaemia (SCI), kidney injury, and bowel and liver or splenic ischaemia within 30 days were recorded. Proximal neck length was measured (on the first post-operative CT scan) from the proximal edge of the stent graft to the start of the aneurysm (in the native aorta) or to the proximal edge of the old stent graft (if a redo case). Proximal neck length was not measured if there was no completion CT or the ISLF graft landed in a proximal thoracic endovascular aortic repair (TEVAR).

Kidney injury was defined as the need for dialysis or > 50% increase in serum creatinine. Bowel and liver or splenic ischaemia was defined as the need for surgery or verification with endoscopy or radiology. Stroke was confirmed with radiological imaging and neurological evaluation, and SCI by physical examination by a vascular surgeon in addition to neurological consultation and radiological imaging when deemed necessary. SCI was defined as onset of paraplegia, paraparesis, paraesthesia, and faecal or urinary incontinence. All participating centres had specific spinal protection protocols that were followed and rescue protocols in case of SCI symptoms, including raised mean arterial pressure, oxygenation, and haemoglobin (> 100 g/L). If the symptoms were not alleviated by these measures, a cerebrospinal drain was inserted.

Follow up was clinical and imaging at least annually to assess bridging stent graft patency and endoleaks.

Overall survival and aortic and ISLF related re-intervention rates were analysed in addition to target vessel instability, which was defined as an endoleak related to the bridging stent graft, disconnection, kink, stenosis, occlusion of the bridging stent, re-intervention to the bridging stent graft, or rupture or death related to the bridging stent graft.¹⁵ Aneurysm expansion was defined as a cumulative expansion of > 5 mm between the pre-operative and latest CT scan.

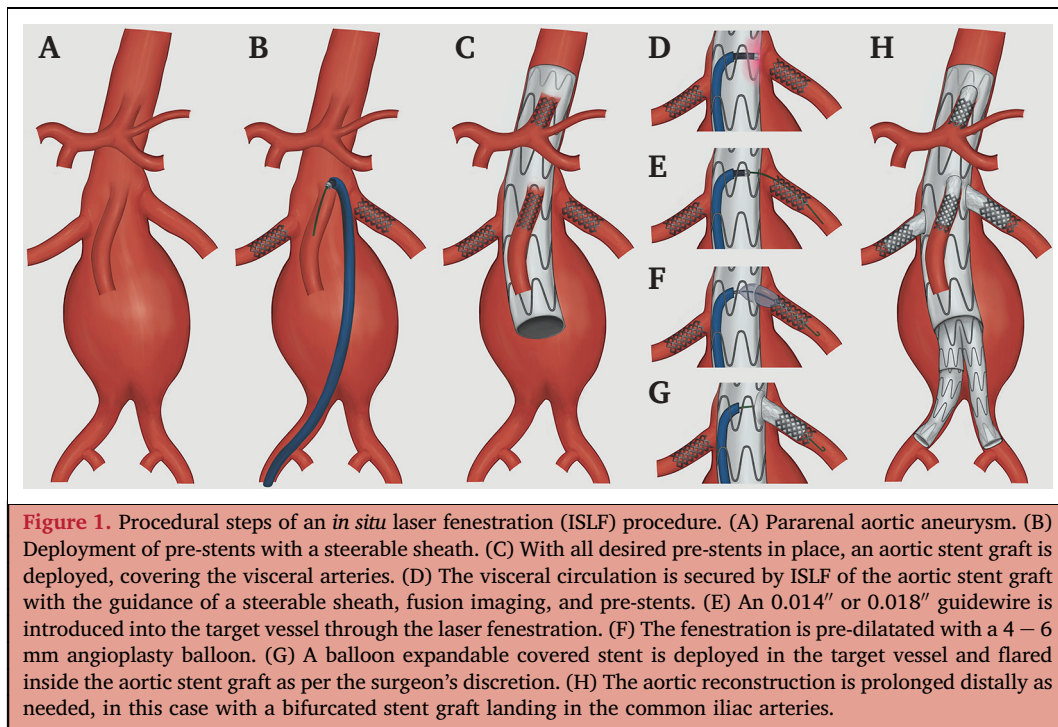


Figure 1. Procedural steps of an *in situ* laser fenestration (ISLF) procedure. (A) Pararenal aortic aneurysm. (B) Deployment of pre-stents with a steerable sheath. (C) With all desired pre-stents in place, an aortic stent graft is deployed, covering the visceral arteries. (D) The visceral circulation is secured by ISLF of the aortic stent graft with the guidance of a steerable sheath, fusion imaging, and pre-stents. (E) An 0.014'' or 0.018'' guidewire is introduced into the target vessel through the laser fenestration. (F) The fenestration is pre-dilated with a 4–6 mm angioplasty balloon. (G) A balloon expandable covered stent is deployed in the target vessel and flared inside the aortic stent graft as per the surgeon's discretion. (H) The aortic reconstruction is prolonged distally as needed, in this case with a bifurcated stent graft landing in the common iliac arteries.

Statistics

Categorical variables were described using frequencies and percentages. Continuous variables were expressed as mean \pm standard deviation. If a non-normal distribution was detected, median and interquartile range (IQR) were given instead. The Shapiro–Wilk test was used for assessing normality. Kaplan–Meier survival estimates were calculated. All calculations were performed using the IBM SPSS Statistics Version 28 software (IBM Corp., Armonk, NY, USA) and $p < .050$ was considered statistically significant.

RESULTS

A total of 716 complex aortic cases were performed during the period: 573 CMDs (all elective), 45 OTS devices (24 acute, 21 elective), 31 chimneys (27 acute, four elective), 30 open procedures (eight acute, 22 elective), and three PMEGs (all acute). A total of 65 ISLFs were performed in 34 patients (21 males) with a mean age of 74 ± 9 years; 32% had undergone earlier aortic procedures. Degenerative aneurysm (71%) was the most common pathology, and the extent of disease was most commonly juxtarenal (56%). The procedure was performed in an acute setting in 79% of the cases (35% ruptures, 35% symptomatic, 6% rescue ISLF after misplaced complex EVAR, 3% acute dissection). Other indications were three accessory renal arteries (9%), two endoleaks with aneurysm expansion after prior EVAR (6%), and two large aneurysms (63 mm, 79 mm) in two females (6%). Median aneurysm diameter was 65 mm (50, 79). Further baseline characteristics are given in Table 1.

The median procedure time was 220 minutes (IQR 161, 276) and the median fluoroscopy time was 73 minutes (IQR

58.5, 115). The number of planned ISLFs was one in 47% ($n = 16$) of cases, two in 27% ($n = 9$), three in 15% ($n = 5$), and four in 11% ($n = 4$) (Table 2). Of all the fenestrations performed, the left renal artery was the most common ($n = 25$), followed by the right renal artery and superior mesenteric artery (SMA) (15 each), while there were seven coeliac fenestrations and three accessory renal arteries. The median proximal neck length achieved was 32 mm (IQR 24, 49) (21 of 34 cases applicable for neck measurement). Pre-stenting was performed on 56 target vessels (86%) with 38 (59%) stent grafts and 17 (26%) balloon expandable uncovered stents. Pre-stenting was not used in five cases: three presented with rupture, one was a rescue ISLF in a branched graft, and one was not pre-stented at the surgeon's discretion. Two additional patients did not have all target vessels pre-stented. Both presented with symptomatic aneurysms; one had no pre-stenting in the left renal artery due to a difficult angulation, and the other patient did not have the SMA pre-stented at the surgeon's discretion. The most common bridging stent was the Advanta V12 (Getinge Maquet, Rastatt, Germany) ($n = 43$, 66%) followed by the Begraft (Bentley InnoMed, Hechingen, Germany) ($n = 13$, 20%), Viabahn VBX (W. L. Gore & Associates, Flagstaff, AZ, USA) ($n = 4$, 6%), and Radix2 (CID S.p.A., Saluggia, Italy) ($n = 1$, 1.5%) (Table 3).

Early (30 day) outcomes

Technical success was achieved in 61 of 65 ISLFs (94%). The four failed cannulations were in renal arteries, three due to difficult angulation (all pre-stented) and one (not pre-stented) dissected during cannulation, which led to subsequent coiling of the vessel. Two of these were in a rupture

Table 1. Baseline demographic and anatomical characteristics of patients ($n = 34$) undergoing *in situ* laser fenestration (ISLF) of visceral aortic stent grafts.

Characteristic	Patients ($n = 34$)
Age – y	73.7 ± 9.1
Male	21 (61.8)
Smoking	15 (44.1)
Ischaemic heart disease	6 (17.6)
Congestive cardiac failure	3 (8.8)
Diabetes mellitus	5 (14.7)
Chronic obstructive pulmonary disease	7 (20.6)
Renal failure	8 (23.5)
Pre-operative creatinine – $\mu\text{mol/L}$	108.6 ± 65.8
<i>Previous aortic surgery</i>	
Endovascular	
EVAR	7 (20.6)
Arch repair ± TEVAR	2 (5.9)
Open	
Ascending aortic repair	2 (5.9)
<i>ASA score</i>	
1	1 (2.9)
2	1 (2.9)
3	18 (52.9)
4	9 (26.5)
5	5 (14.7)
<i>Operative indication</i>	
Symptomatic aneurysm	12 (35.3)
Rupture	12 (35.3)
Accessory renal artery	3 (8.8)
Endoleak and aneurysm growth	2 (5.9)
Rescue ISLF after misplaced c-EVAR	2 (5.9)
Acute dissection	1 (2.9)
Large aneurysm	2 (5.9)
<i>Anatomy</i>	
Degenerative aneurysm	24 (70.6)
Mycotic aneurysm	7 (20.6)
Acute dissection	1 (2.9)
Chronic dissection, aneurysmal degeneration	2 (5.9)
<i>Extent of disease</i>	
Thoracic	1 (2.9)
Thoraco-abdominal	10 (29.4)
Suprarenal	4 (11.8)
Juxtarenal	19 (55.9)
Infrarenal	0

Data are presented as n (%) or mean ± standard deviation. EVAR = endovascular aortic repair; TEVAR = thoracic endovascular aortic repair; ASA = American Society of Anesthesiologists; ISLF = *in situ* laser fenestration; cEVAR = complex endovascular aortic repair.

setting, one symptomatic dilatated chronic dissection with complex anatomy and one previous EVAR with endoleak and expansion.

The median intensive care unit (ICU) and hospital stays were 0 days (IQR 0, 1) and 9 days (IQR 3, 31), respectively. The median ICU stay for ruptures was slightly longer (1 day; IQR 0, 3). In the acute group ($n = 27$), four patients (15%) died within 30 days, all were treated for a rupture; three patients (11%) developed permanent SCI, two of them were paraplegic. The first case had a previous arch branched repair and required a single ISLF as rescue for the left renal after a misplaced OTS branched device during a procedure that took 374 minutes and total aortic coverage from aortic zone 0 – 9. The second paraplegic case presented with a type 2 thoraco-abdominal aortic aneurysm (TAAA) rupture and underwent a TEVAR using a newly developed OTS device with a custom fenestration for the SMA and two renal ISLFs and an EVAR (coeliac was chronically occluded). The procedure took 290 minutes and the total aortic coverage was from aortic zone 3 – 10. The third patient with SCI developed paraparesis after a three ISLF procedure due to a symptomatic type 3 TAAA. The procedure took 434 minutes and total aortic coverage was from aortic zone 5 – 10. One patient (4%) suffered a stroke and seven patients (26%) developed an acute kidney injury, of which two (7%) were permanent. Two patients (6%) developed end organ infarction peri-operatively; both were treated for ruptures: one had a smaller renal infarction, while the other suffered from multiple infarcts (cerebral, hepatic, renal). In the non-acute group ($n = 7$), no patient died or had a major complication within 30 days. Three ISLF related re-interventions were performed within 30 days, involving four of 65 (6%) target vessels (two stenosed stents, one type IIIb, and one type IIIc endoleak). One (2.9%) non-ISLF related aortic re-intervention was performed within 30 days due to an access complication. See Table 4 for complications within 30 days.

Follow up

The median follow up was 16 (IQR 5, 22) months. Among those surviving the peri-operative period (30 of 34) three died during follow up (days 186, 291, and 671) of unknown causes. The patient who died on day 186 was a 60 year old who had a ruptured aneurysm and a prolonged hospital stay of 86 days due to a decompressive and exploratory laparotomy for mesenteric haematoma and relining of a kinked SMA stent graft. The patient who died on day 291 was a 80 year old male who died suddenly at home without known cause. On day 671, a 77 year old male with an

Table 2. Number of *in situ* laser fenestrations (ISLFs) in relation to aortic disease localisation.

ISLF – n	Juxtarenal	Suprarenal	Thoracic	Thoraco-abdominal	Total
1	12	0	1	3	16
2	4	1	0	4	9
3	3	1	0	1	5
4	0	2	0	2	4
Total	19	4	1	10	34

ISLF = *in situ* laser fenestration.

Table 3. Procedural data for the *in situ* laser fenestration of visceral aortic stent grafts procedures.

Variable	Patients (n = 34)/ ISLFs (n = 65)
Procedure time – min	220 (161, 276)
Fluoroscopy time – min	73 (58, 115)
Stent graft	
Endurant (Medtronic, Inc., Minneapolis, MN, USA)	13 (38.2)
Zenith Alpha (Cook Medical, Bloomington, IN, USA)	11 (32.4)
TX2/CMD/TFFB (Cook Medical, Bloomington, IN, USA)	10 (29.4)
Pre-stent	56 (86.2)
Advanta/iCast V12 (Getinge Maquet, Rastatt, Germany)	24 (36.9)
Begraft (Bentley InnoMed, Hechingen, Germany)	15 (23.1)
Visi-Pro (eV3 Endovascular, Plymouth, MN, USA)	8 (12.3)
Radix2 (CID S.p.A., Saluggia, Italy)	8 (12.3)
Besmooth (Bentley InnoMed, Hechingen, Germany)	1 (1.5)
Bridging stent	61 (93.8)
Advanta/iCast V12 (Getinge Maquet, Rastatt, Germany)	43 (66.2)
Begraft (Bentley InnoMed, Hechingen, Germany)	13 (20.0)
Viabahn VBX (W. L. Gore & Associates, Flagstaff, AZ, USA)	4 (6.2)
Radix2 (CID S.p.A., Saluggia, Italy)	1 (1.5)

Data are presented as n (%) or median (interquartile range). CMD = custom made device.

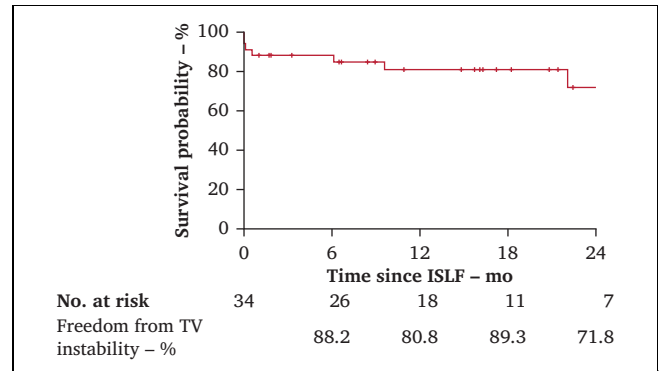
endoleak of unknown type on latest follow up died of unknown cause before any further interventions. The cumulative overall survival probability at six months, one year, and two years was 88% (standard error [SE] 0.06), 81% (SE 0.07), and 72% (SE 0.10), respectively (Fig. 2).

Of the 61 bridging stent grafts that were successfully deployed, six (10%) target vessel related instabilities were detected: two (3%) type III endoleaks (one type IIIc, one

Table 4. Complications within 30 days in patients (n = 34) following *in situ* laser fenestration of visceral aortic stent grafts.

Complication	Total (n = 34)	Emergency (n = 27; 79.4%)	Non-emergency (n = 7; 20.6%)
Death	4 (11.8)	4 (14.8)	0
Spinal cord ischaemia			
Transient	0	0	0
Permanent	3 (8.8)	3 (11.1)	0
Stroke	1 (2.9)	1 (3.7)	0
Acute kidney injury			
Transient	5 (14.7)	5 (18.5)	0
Permanent	2 (5.9)	2 (7.4)	0
Mesenteric ischaemia	0	0	0

Data are presented as n (%).

**Figure 2.** Cumulative Kaplan–Meier estimate of overall patient survival over two years following *in situ* laser fenestration (ISLF) of visceral aortic stent grafts. TV = target vessel.

type IIIb), were detected during the peri-operative period, and four (7%) stent stenosis, two were detected during the peri-operative period and two were detected on the 30 day follow up CT and were subsequently treated on post-operative day 38. All target vessel related issues required intervention (one percutaneous transluminal angioplasty, five relined with stents, n = 6, 10%) Additionally, one proximal endoleak of unknown aetiology was detected during follow up. Freedom from target vessel instability at six months until end of follow up was 89% (SE 0.04) (Fig. 3).

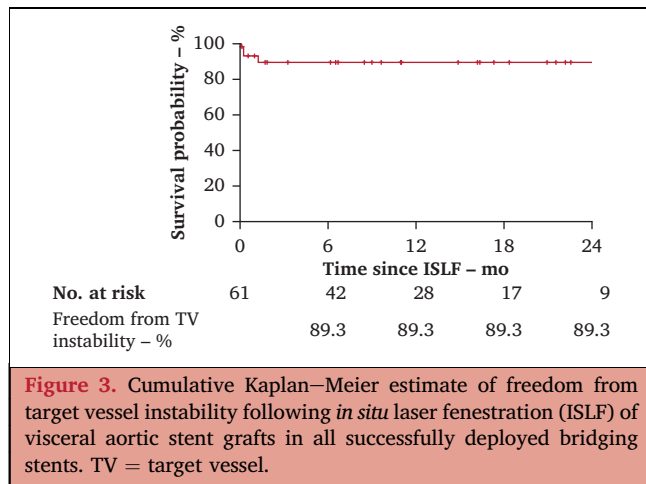
Five of 34 patients (15%) underwent a non-ISLF related aortic re-intervention after the initial 30 day post-operative period (coiling of type Ib endoleak, iliac extensions due to type Ib endoleak, kissing stent due to compression of limbs, re-lining of a non-ISLF renal fenestration, and inferior mesenteric artery embolisation due to an endoleak).

On the latest follow up scan, three of 34 patients (9%) had a type Ia endoleak. One had three fenestrations and a chimney for the coeliac trunk and a proximal sealing zone of 48 mm. The second case was a single fenestration for a renal artery, and the proximal sealing zone was 40 mm. The last case was a proximal cuff extension due to an endoleak and rapid aneurysm growth after a previous EVAR; both renals were planned for revascularisation with one being successful, although the length of the proximal seal was unknown because the only post-operative imaging was ultrasound.

The median change in aneurysm diameter was –6.5 mm (IQR –11, 0), with two patients (6%) demonstrating expansion of the aneurysms. One (1.6%) target vessel had a non-occlusive wall thrombus in the bridging stent (SMA) treated with direct oral anticoagulants, but all successfully deployed ISLF bridging stents were patent without signs of bridging stent related endoleak with assisted primary patency of 100% (61/61). See Table 5 for further data on ISLFs.

DISCUSSION

The current report confirms an acceptable ISLF technical success rate of 94% in a challenging group of complex urgent aortic procedures. Also, midterm patency (100%),



overall survival probability (73%), and freedom from target vessel instability (90%) were in an acceptable range during a median follow up of 15.5 months for a cohort with a high proportion (79%) of acute cases, with a sizeable number of deaths and complications within 30 days being in patients treated acutely due to a ruptured or symptomatic aneurysm. Le Houérou *et al.*⁸ demonstrated acceptable two year midterm results for a series on complex AAAs unsuitable for a custom stent graft or open surgery, with technical success of 97%, two year overall survival of 73%, and stent related re-intervention free survival and aortic re-intervention free survival of 90.6% and 70%, respectively. Although 80% of these cases were deemed to be at a high risk of rupture, only 39% were symptomatic and 4.5% presented with rupture. In comparison, the present cohort had 35% ruptures and an additional 35% were symptomatic. Similarly, ISLF has demonstrated promising results in elective settings¹⁰ with 96% technical success and a 30 day mortality rate of 10%, while data on midterm patency and re-intervention rates have not yet been reported.

Despite these promising results in emergency settings, every case still needs to be evaluated on an individual basis. When anatomically feasible, OTS devices should be considered as the first choice. However, a narrow aortic diameter at visceral level often prohibits the use of branched endografts,¹⁶ which are the devices available for OTS use in the juxta- and pararenal aorta. This is mirrored in the current cohort being mostly juxtarenal aneurysms

(56%), while two of the 10 TAAAs were Crawford–Safi type 2. Also, branched grafts often require more extensive aortic coverage, increasing the risk of SCI in the emergency setting when staging is not possible.^{5,17} A median aortic neck seal of 32 mm was achieved in the current cohort. This is a longer seal than often accepted for standard EVAR but also slightly shorter than what is often aimed for in CMD devices (40 mm). However, in this emergency cohort, reducing the number of fenestrations is also a way to simplify the procedure. The use of OTS branched devices in the same cohort would have resulted in significantly more extensive aortic coverage and thus theoretically increase the risk of SCI. The length of seal and number of varied fenestrations based on individual anatomical characteristics is detailed in Table 4. With this, the authors aimed for an acceptable seal while simultaneously limiting the coverage in accordance with the most recent European Society for Vascular Surgery (ESVS) guidelines.¹⁸

Other possible solutions when the anatomy is unsuitable for branched OTS devices are PMEGs and CheVAR. In comparison with ISLF results, PMEGs have acceptable mortality (0 – 8%) and good success rates (87.5 – 100%)¹⁹ but the extended modification time and high level of expertise often renders them not applicable in the acute setting. Chimney EVARs carry an increased risk of type Ia endoleak^{3,4} and should, ideally, not be considered for more than two fenestrations, even in the emergency setting.¹⁸ An additional advantage of ISLF devices in emergency settings is the rapid exclusion of the aneurysm compared with OTS branched devices or PMEGs where the aneurysm is perfused via open branches or fenestrations until the final bridging stent is deployed. There are also new designs emerging, such as single fenestrated devices, where the SMA is secured by a pre-made fenestration relying on ISLFs to revascularise the renal and coeliac arteries. While awaiting OTS devices to be used in patients who are unfit for open repair, innovations like these could be important aids.^{20,21}

Fusion imaging guidance^{10,22} and pre-stenting⁸ are preferable in ISLF to guide correct positioning in the fenestration process. The downsides of pre-stenting are the additional time required, which delays aortic coverage in the emergency setting, and the technical problems that occur if the pre-stent is suboptimally placed. Pre-stenting was performed on 85% of target vessels in the current cohort despite a high proportion of emergency cases.

Table 5. Target vessel (TV) related data at end of follow up following *in situ* laser fenestration (ISLF) of visceral aortic stent grafts.

TV	<i>n</i>	Successful ISLF	TV instability requiring intervention during follow up	Bridging stent related endoleak at end of follow up	Thrombosis requiring anticoagulation at end of follow up	Occlusion at end of follow up
Coeliac artery	7	7	1	0	0	0
SMA	15	15	2	0	1	0
Left renal	27	25	1	0	0	0
Right renal	16	14	2	0	0	0
Total	65	61 (93.8)	6/61 (9.8)	0	1/61 (1.6)	0

Data are presented as *n* or *n* (%). TV = target vessel; ISLF = *in situ* laser fenestration; SMA = superior mesenteric artery.

Although it is not vital for a successful ISLF, pre-stenting in addition to fusion does facilitate the possibility of successful recanalisation, even in emergency cases. One renal artery, which was not pre-stented, was dissected during the laser fenestration process; pre-stenting could have potentially prevented this complication.

All four unsuccessful ISLFs were renal arteries, which was possibly related to angulated anatomies and smaller diameters when compared with the SMA and coeliac artery. Additionally, two had undergone a prior EVAR operation, which can increase the technical difficulty of ISLF owing to the presence of bare metal top stents in the desired aortic segment.

In two cases, the patients developed end organ infarction despite successful ISLF. Both were operated on for a ruptured aneurysm and had a longer than median procedure time. While there have been concerns regarding the risk of fabric embolisation during ISLF, this complication has never been reported and an animal study did not demonstrate any emboli because of ISLF.¹³ Possible causes for infarction in complex ruptured cases could be, amongst other things, hypovolaemic episodes, delayed heparinisation with suboptimal activated clotting time, or emboli from the thrombotic aneurysmal wall.

The sequence of revascularisation of the renovisceral vessels is a matter of debate. The SMA is a vital vessel to revascularise, which is the basis for starting with it. At the same time, the intestine tolerates a longer period of ischaemia compared with the kidneys, which are more sensitive, which would suggest that the renal arteries should be revascularised first. In most of the current cases, the SMA was revascularised first, followed by the renal arteries and finally the coeliac artery. Of the two patients who suffered end organ infarction, one developed a kidney injury. In addition, six more patients developed a kidney injury, two of which were permanent. Even though these kidney injuries occurred in acute patients, this remains a concerning proportion of 21% kidney injuries (6% permanent). This proportion of kidney injury could possibly be reduced by stenting the renal arteries before the SMA. It should, however, be noted that there were no cases of bowel ischaemia in the cohort, which could be a positive effect of the chosen sequence. In recent years, an OTS CMD comprising a single fenestration for the SMA has also been used so that the surgeon can primarily focus on the renal arteries.^{20,21} There are other methods in use to decrease the visceral ischaemia dilemma, such as intra-operative, temporary, balloon gutter leaks and single fenestrated PMEGs, that need to be further investigated.

ISLF in complex AAAs involving visceral arteries seems to have promising technical success and midterm outcomes, even in the emergency situation. Long term patency and results are still unclear and, as of the most recent ESVS guidelines, this technique is not recommended for use outside emergency cases or investigational studies.¹⁸

Important limitations of this study were the relatively short follow up period of a median 15.5 months (464 days) and the retrospective nature of the study, with the risk of

selection bias, performed in three highly specialised aortic centres, which lessens the general applicability to ISLF in real world settings.

In conclusion, ISLF is a promising tool for emergency endovascular procedures in complex anatomies when open surgery is not an option. Long term follow up data are still missing required.

CONFLICT OF INTEREST

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