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Endovascular abdominal aortic repair and concomitant intraprocedural endovascular interventions: Our single-center experience

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ABSTRACT

Objectives: The aim of this study was to retrospectively evaluate patients who underwent endovascular treatment due to abdominal aortic aneurysms (AAAs) and ruptured AAAs at our center, especially in terms of secondary interventions performed during endovascular treatment and to compare the obtained data with the current literature.

Patients and methods: A total of 137 patients underwent endovascular stent graft implantation due to AAA and ruptured AAA at our center, between 2004-2012. Eighty-one patients whose preoperative CT scans could be obtained were recruited in the study. Demographic data, preoperative aneurysm diameters, aneurysm neck lengths, neck angles, success rate for stent placement, perioperative mortality rate (<30 days), aneurysm-related mortality rate (<30 days), secondary intraprocedural endovascular interventions, and time of discharge from the hospital were evaluated.

Results: Seventy-three of the patients were male and eight were female, and their ages were between 51-89 (mean: 70.1±8.8) years. The largest aneurysm diameters varied between 53 and 110 (mean: 63.8±12.9) mm. Aneurysm neck lengths varied between 0-60 (mean: 24.1±12.4) mm. The angle between aneurysm neck and suprarenal aorta was between 17-90 (mean: 34.9±15.9) degrees. Of our patients, 75 were treated due to AAA and 6 were treated due to ruptured AAA. The mean time of discharge from the hospital was 4.54±3.6 (range, 2-24) days for patients treated electively. The mean time of discharge from the hospital was 10.2±8.7 (range, 3-25) days for the six patients operated due to ruptured AAA. Perioperative mortality (<30 days) was not detected in any of the patients treated electively and perioperative mortality rate (<30 days) in ruptured AAA group was 16.6%. Aneurysm-related mortality (<30 days) was not detected in any of the 81 patients. Although secondary endovascular interventions were required in 14 of 81 patients (17.2%) during the procedure, stent graft placement success rate was found to be 100%.

Conclusion: Our study results demonstrate that endovascular treatment is a method that may be performed safely with a high technical success rate, and decreases perioperative mortality rate, aneurysm-related mortality rate, and time to discharge. Concomitant interventions required during the procedure suggest that endovascular treatment must be performed by experienced teams with sufficient knowledge.

Keywords: Abdominal, aortic aneurysm, endovascular procedures.

An abdominal aortic aneurysm (AAA) is defined as an irreversible dilatation of the abdominal aorta to a diameter greater than 3.0 cm or 1.5 times its normal anteroposterior diameter.[1] Patients are mostly asymptomatic and are generally diagnosed upon ultrasonography, computed tomography (CT) or magnetic resonance imaging performed due to other reasons. Patients are usually lost to complications such as rupture or dissection.[2,3] There are two approaches for the treatment of aortic aneurysms. These are conventional open surgery method that involves laparotomy and placement of prosthetic graft to the aneurysmal segment, and endoluminal stent-graft placement, which is a minimally invasive method compared to the open surgery. Open surgery has been used as the primary method for the treatment of AAA

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for many years. Despite the high success rate of this method, severe operational complications may still be observed. Although endovascular treatment was initially a method recommended for the treatment of high-risk surgical patients, it has become widely applicable due to the developments in stent-graft technology and increased user experience.

During the endovascular treatment of AAA, foreseeable or occasionally unforeseeable concomitant interventions may be required. Today, endovascular treatment of aortic aneurysms is possibly one of the most difficult of the endovascular procedures in interventional radiology. Undoubtedly, it requires an expertise in catheter and guide wire manipulation. Moreover, the operator must have an extensive knowledge of balloon angioplasty and stenting.[4] In addition, preoperative CT angiography has critical importance in patient selection. Experience, selection of the suitable patient and angiographic equipment are the most important factors that determine success in stent graft implantation.

The aim of this study was to retrospectively evaluate 81 patients who underwent endovascular treatment due to AAA and ruptured AAA at our center between 2004-2012 especially in terms of secondary interventions performed during endovascular treatment and to compare the obtained data with the current data from the literature.

PATIENTS AND METHODS

Our study was performed within the scope of the research project no. KA12/146 with the permission of our University Faculty of Medicine, Board of Research Studies Ethics Committee. In this study, 137 patients who underwent endovascular stent graft implantation due to AAA and ruptured AAA at our hospital, departments of cardiovascular surgery and interventional radiology unit between 2004-2012 were evaluated. The study was designed by analyzing the patients' files, our University Hospital Cardiovascular Surgery and Interventional Radiology Archive, CT and MRI Archive, Avicenna and Nucleus Hospital Information System, patients' previous examinations and procedures performed at other centers. Eighty-one patients whose preoperative CT scans could be obtained were recruited in the study. Fifty-six patients who were refereed from other centers were excluded from the study whose preoperative CT scans could not be obtained or who do not have good quality images. The evaluation was retrospective and included the patients':

1. Demographic data
2. Preoperative aneurysm diameters, aneurysm neck lengths, neck angles
3. Success rate for stent placement
4. Perioperative mortality rate (<30 days)
5. Aneurysm-related mortality rate (<30 days)
6. Secondary endovascular interventions performed during the procedure (additional interventional radiology procedures or conversion to open surgery)
7. Time of discharge from the hospital.

Of our patients, 75 were treated due to AAA and six due to ruptured AAA.

Procedures were performed in angiography laboratory by a team comprising interventional radiologists, cardiovascular surgeons, and anesthesiologist. Preoperatively, the patients' suitability to endovascular treatment was analyzed via contrast CT scan. Moreover, required measurements were performed to analyze the type and dimensions of the graft to be selected, iliac and femoral arteries were evaluated for their suitability to intervention, and the side of femoral artery to which the delivery system of the main body will be sent was determined. Preoperatively, all patients were informed and the content forms were obtained.

Following the patient's placement on angiography table and establishment of standard sterile conditions, inguinal region was opened via cut-down incision by the cardiovascular surgeon and main femoral arteries were surgically exposed. Proximal and distal segments of the exposed femoral arteries were encircled by 'vessel loop' to prevent hemorrhage during the procedure. After the appropriate anesthesia was administered and femoral regions were opened via cut-down incision, through the femoral artery contralateral to the side to which the delivery system of the main body will be sent, aortography performed with a marked pigtail catheter. Based on the aortography performed, the length of the segment to be repaired, length and angle of the aneurysm, iliac artery stenosis, and angulations of iliac arteries were evaluated in terms of their concordance with the known criteria.[4-8] The graft's anchor points on proximal and distal ends on the nondiseased portion of the vessels were measured and, the diameter of the graft was calculated by adding an oversizing factor of 20%. Then, through femoral artery ipsilateral to the side where the main body will be sent main body of the stent graft was placed on the infrarenal portion of the abdominal aorta over the rigid guide wire. Then, using the contralateral sheath, via an appropriately angulated catheter and a guide wire, contralateral leg of the main body was catheterized and again, over the rigid guide wire, contralateral leg was added to the main body. In the control angiography performed after the procedure, it was found that aneurysm sac was unfilled, renal arteries, both of the common iliac arteries and external iliac artery were patent, the procedure was terminated, and the patients were sent to the intensive care unit.

When we first started endovascular repair, we preferred epidural anesthesia in first cases. However, after treating seven patients under epidural anesthesia, the clinic protocol changed in 2005, and we began using local anesthesia. Paraplegia in one patient following epidural anesthesia was the main reason for changing the anesthesia strategy. Eventually, in the vast majority of the cases, intravenous sedation and local anesthesia was preferred. When general anesthesia became necessary after local anesthesia failed, it was administered in a standard manner.

After their discharge, patients were followed up both by cardiovascular surgery and interventional radiology units, and evaluated in terms of graft migration, leakage and potential complications with CT angiography.

RESULTS

The demographics, and comorbidities in patients undergoing endovascular repair are summarized in Table 1. Of our patients, 74 were treated due to AAA and six were treated due to ruptured AAA. One patient was treated under emergency conditions due to the presence of both abdominal and thoracic aneurysm and the thoracic aneurysm was ruptured.

In 81 patients, the widest portion of aneurysm was measured to be between 53-110 (mean: 63.8±12.9) mm. The aneurysm neck lengths were between 0-60 (mean: 24.1±12.4) mm. The angle between aneurysm neck and suprarenal aorta was between 17-90 (mean: 34.9±15.9) degrees.

Of the 81 patients, aorto-bi-iliac graft was used in 78 patients, thoracic graft in two patients and aorto-uni-iliac graft in one patient. Additional two thoracic grafts were used in the patient in whom aorto-uni-iliac graft was used. Of the 78 patients who received aorto-bi-iliac graft, Gore Excluder (W. L. Gore and Associates, Flagstaff, Arizona.) was used in 50 patients, Medtronic Endurant (Medtronic Vascular, Santa Rosa) in 22 patients and Medtronic Talent (Medtronic Vascular, Santa Rosa) in six patients. Gore TAG (W. L. Gore and Associates, Flagstaff, Arizona) was used in two patients who received thoracic graft. In one patient who received aorto-uni-iliac graft, Medtronic Talent (Medtronic Vascular, Santa Rosa) was used.

The mean time of discharge from the hospital was between 2-24 (mean: 4.54 ± 3.6) days for the 74 patients treated electively. Of six patients treated

Table 1. The demographics, and comorbidities of the patients

Demographic data	n	%	Mean±SD	Min-Max
Age (year)			70.1±8.8	51-89
Sex				
Female	8	9.8		
ASA Class III	36	44.4		
ASA Class IV	15	18.5		
ASA Class V	1	1.2		
Smoking	50	61.7		
Hypertension	39	48.1		
Diabetes mellitus	8	9.8		
Hyperlipidemia	16	19.7		
Coronary artery disease	35	43.2		
Chronic kidney disease (compensated)	8	9.8		
Chronic renal insufficiency	4	4.9		

SD: Standard deviation; ASA: American Society of Anesthesiologists classification.

Table 2. Complications related with surgery and graft deployment

	n	%
Groin hematoma	4	4.9
Postsurgical groin pseudoaneurysm	2	2.5
Groin infection	2	2.5
Groin lymphocele	-	-
Vascular injury	2	2.5
Distal embolization	-	-

Table 3. Systemic complications after endovascular repair

Systemic complications	n	%
Contrast nephropathy	11	13.6*
Intestinal ischemia	1	1.2†
Acute pancreatitis	1	1.2
Epidural hematoma	1	1.2
Pneumonia	1	1.2‡

* Dialysis was needed in 6 of 11 patients; † Discharged on the 24th day due to intestinal ischemia, right hemicolectomy and small bowel resection; ‡ Discharged on the 15th day due to pneumonia developed in the intensive care unit on the 2nd day.

Table 4. Graft-related complications

Graft-related complications	n	%
İnferior migration (during procedure)	4	4.9
Endoleak (immediately after graft deployment)	32	39.5
Endoleak (during follow-up)	18	22.2
Graft leg thrombosis or leg ischemia	5	6.2
Kinking	2	2.5
Aortic thrombosis	1	1.2
Graft infection	-	
Aorta enteric fistula	-	

Table 5. Types of endoleak (endoleaks that occur immediately after graft deployment or during follow up)

	Immediately after graft deployment		During follow-up*	
Endoleak type	n	%	n	%
Type 1	26	32	4	4.9
Type 1a	20†		3	
Type 1b	6‡		1	
Type 2	6	7.4	13	16
Type 3	-	-	1	1.2
Type 4	-	-	-	-
Type 5	-	-	-	-

* Except two patients who died in the early period (5th day and 40th day), the average follow-up period was calculated as 42 months (min 3- max 90 months); † Six of the 20 patients treated with aortic balloon dilatation, and rest of 14 patients treated with aortic extension; ‡ Treated with iliac extension.

due to ruptured AAA, one was lost due to cardiac arrest that developed in the intensive care unit five days after the operation, and the mean time of discharge from the hospital was between 3-25 (mean: 10.2±8.7) days for the remaining five patients. As described previously, one patient with both abdominal and thoracic aneurysm was treated due to ruptured thoracic aneurysm and was lost after 60 days.

Perioperative mortality (<30 days) was not detected in any of the 74 patients treated electively. Of six patients who treated due to ruptured AAA, one was lost five days after the procedure and perioperative mortality (<30 days) in ruptured AAA group was

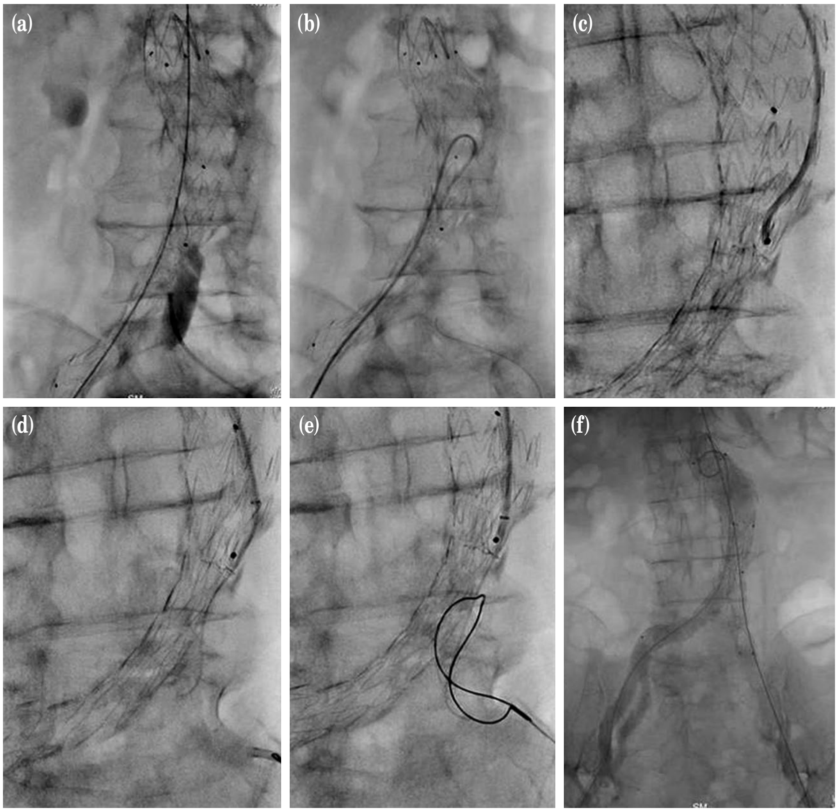

Figure 1. Intraprocedural DSA images of male patient. It was not possible to advance to the contralateral leg from the **(a)** contralateral and ipsilateral **(b)** entry points since the main body contralateral leg was embedded into the thrombus. **(c-f)** Establishment of the 'through and through loop' by catching the snare sent from the contralateral side and guide wire sent from the axillary artery and consequent successful catheterization of the contralateral leg.

DSA: Digital subtraction angiography.

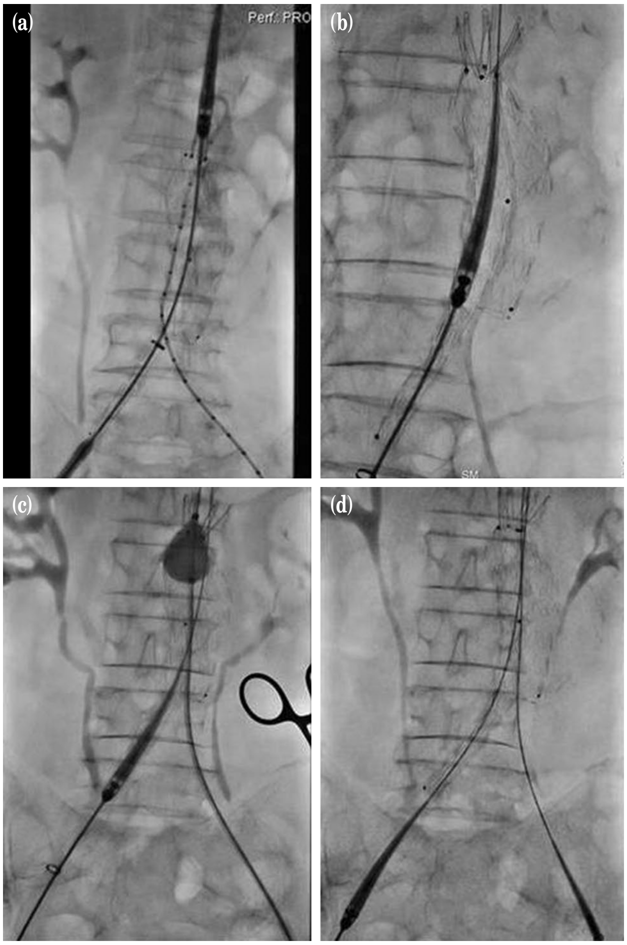

Figure 2. Intraprocedural DSA images of male patient. **(a, b)** The inability to retract the delivery system of the stent graft main body due to the stenosis in the right iliac artery. **(c, d)** Inflation of the balloon at the neck of the aneurysm, consequent generation of resistance for the stent graft and prevention of the stent graft from sliding down and successful retraction of the delivery system.

DSA: Digital subtraction angiography.

found to be 16.6%. Aneurysm-related mortality (<30 days) was not observed in any of the 81 patients. One patient who treated due to ruptured AAA was lost to cardiac arrest that developed in the intensive care unit within the first 30 days (5^{th} day) after the procedure.

Complications related with surgery and graft deployment (Table 2), systemic complications (Table 3), graft related complications (Table 4) and types of endoleaks (Table 5) are summarized in the tables and are also be a subject of another study

Stent graft placement was successfully completed in all of the 81 patients. In 14 of the 81 patients (17.2%), concomitant endovascular interventions were required during the stent graft implantation. In five of these 14 patients, after placement of the main body, various types of catheters and guide wires could not be advanced to the contralateral leg of the main body for contralateral leg placement, and therefore, snare technique was used to overcome this problem. In four of these five patients, within the graft, catheter and guide wire were rotated from the ipsilateral femoral artery and in one of these five patients, snare technique was performed via the axilla artery (Figure 1).

In one patient, ruptured infrarenal aneurysm had a very large diameter (9 cm) and aortic stent diameter would not be sufficient. Therefore, uni-iliac graft was placed on the aorta and by placing two thoracic grafts proximal to this graft in order to create a link, the plan was to disrupt the connection between the aneurysm and blood supply. However, after the placement of uni-iliac graft, thoracic graft sent from the femoral entry point could not be advanced to the aorta within the uni-iliac graft. Although balloon dilatations were performed in the graft leg, graft still could not be advanced to the aorta. It was possible to enter through the axillary artery and establish a 'through and through' loop between the femoral entry point and axilla, and by pulling the guide wire from both sides and generating a certain force, thoracic stents were advanced to the aorta and opened in appropriate positions.

In another patient treated due to ruptured AAA, main body of the stent graft could not be advanced to the aorta because of the tortuosity and stenosis in the iliac artery. Thus, balloon dilatation was performed on the stenotic segments but this was unsuccessful. Then, similarly, it was possible to enter through the axillary artery and establish a 'through and through' loop and by mutually pulling the guide wire from both sides and generating a certain force, the main body was advanced to aorta. In another patient, after opening the main body, efforts were made to retract the delivery system with appropriate manipulations but the shaft of the delivery system was stuck due to stenosis in the iliac artery and started to pull the stent back. At this point, the balloon sent through contralateral side was inflated at the neck the aneurysm, the shaft of the stent graft was retracted while inflating the balloon and by this way, with the inflated balloon, a resistance was generated for the stent graft and the stent graft was prevented from sliding down (Figure 2).

In one patient, due to the presence of a certain angulation in the iliac arteries and aorta, when the

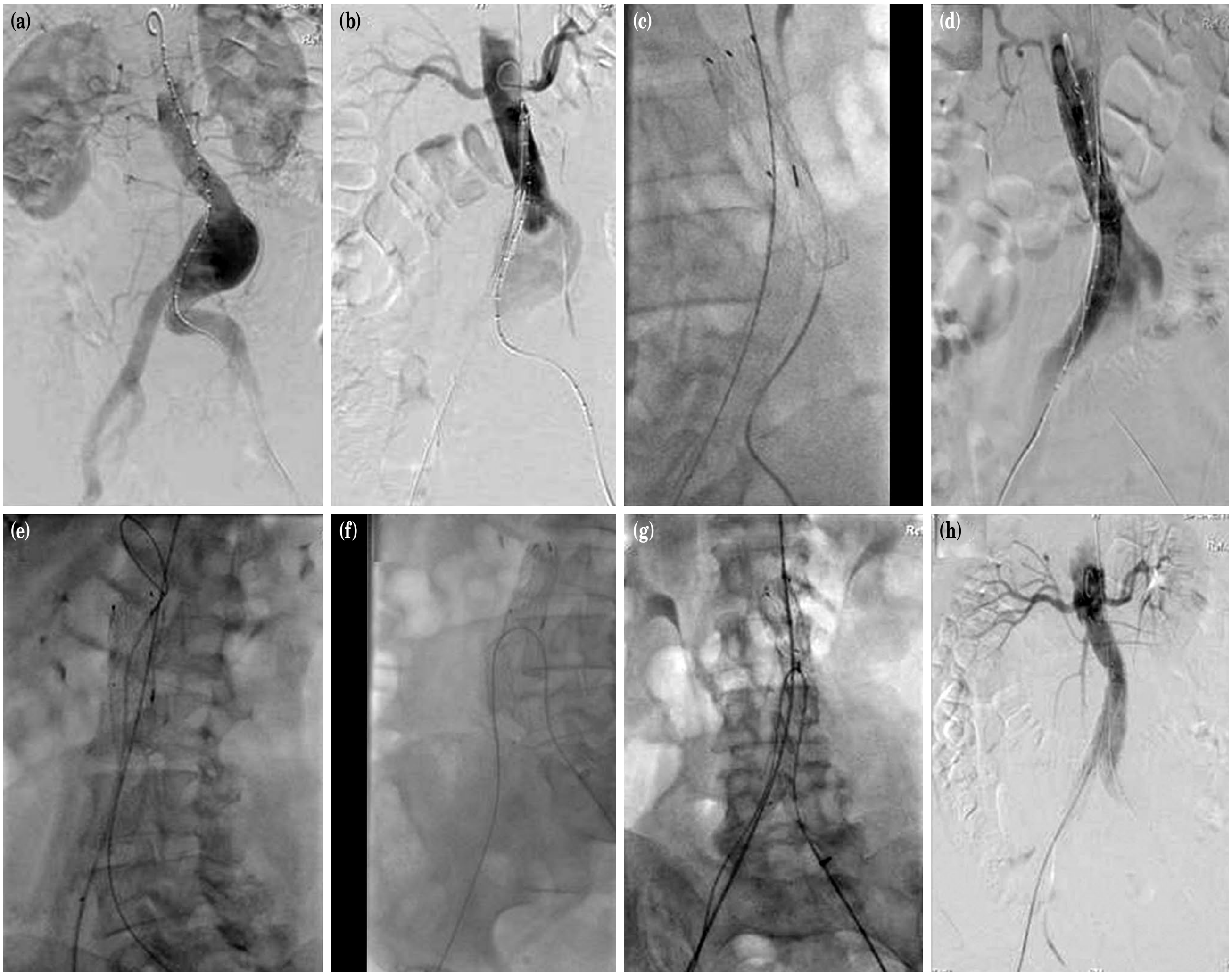

Figure 3. Intraprocedural DSA images of male patient. **(a-d)** Proximal migration of the main body during the procedure and covering of the renal arteries by the graft. **(e-h)** Pulling the stent graft distally with respect to the renal arteries via 'pull down' method by generating a 'through and through loop' between both femoral arteries.

contralateral leg was sent after the insertion of the main body, the main body migrated approximately 2 cm proximally during the passage of contralateral leg, and covered the renal arteries. Thus, urgently, guiding catheter and snare were sent from ipsilateral side, and the guide wire sent contralaterally was caught by the snare and a 'through and through' loop was established. A force was generated by pulling both ends of the guide wire and the stent graft was pulled distally with respect to the renal arteries (Figure 3).

In another patient, while the contralateral leg was sent through the left femoral artery, it was found that contralateral leg was 1 cm longer and could potentially obstruct the internal iliac artery. Thus, contralateral leg was opened after placing it approximately 0.5 cm proximally with respect to the normal marker. In images collected during the procedure, it was found that the non-covered portion of the contralateral leg extended toward the lumen of the main body proximally. Thus, in order to fix the non-covered portion of the contralateral leg and prevent a thrombosis that may occur at this level, an iliac extension was inserted ipsilaterally. In images collected after the procedure, it was found that the non-covered portion of the left contralateral leg extending toward the right leg was back to normal. In two patients, the main body could not be advanced due to the severe stenoses in iliac arteries and after performing balloon dilatation, the main body was advanced to the aorta. In two patients, due to iliac tortuosity, stents of the iliac extensions that were placed did not open and thus, stents opened only after inflating a PTA balloon at the segments that did not fully open.

DISCUSSION

Endovascular treatment of AAAs is a less invasive method compared to surgery. It is increasingly used due to its lower mortality and morbidity rate, shorter time of intensive care and hospital stay, decreased blood loss and reduced need for transfusion, and the potential to be performed on elderly patients and patients with other systemic problems.[9-11]

Abdominal aortic aneurysms are mostly observed among the older population and AAA develops in 5% of males aged 65 or above.[12] In large imaging studies, AAA prevalence among males aged 65 and 85 was found to be between 4.5-7%.[13,14] In our study, the mean age of patients was 70.1 years. Prevalence of AAA is less among females than males.[15] In our patient group, males were the majority (73 males, 8 females).

Before the procedure, patients must be evaluated by CT angiography for the concordance of the length of the segment to be repaired, the length and angle of the aneurysm neck, aneurysm diameter, iliac artery stenosis, and the angulations in the iliac artery with the known criteria, and the extension of aneurysm to internal-external iliac arteries.[4-8] In our study, patients were evaluated before the procedure via CT angiography for whether they had the suitable anatomic criteria for the procedure. Traditionally, the angle between aneurysm neck and suprarenal aorta must be less than 60 degrees. Moreover, aneurysm neck length must be at least 10 mm (>15 mm for some grafts available in the market).[4,16] An angulation greater than 60 degrees and a short aneurysm neck might affect the attachment of the stent to the aneurysm and the risk of migration.[4] Also, angulations greater than 60 degrees might lead to stent fractures. In our study, stent graft implantation was successfully performed on 18 patients with an aneurysm neck length below 15 mm. In one of our patients treated due to ruptured AAA, although the aneurysm originated immediately after the renal arteries, the patient had a high risk of operative mortality and therefore the decision was made to treat the patient with endovascular approach and stent graft implantation was successfully performed. Other than this, one patient who had insufficient neck length due to an infrarenal aneurysm which included the left renal artery was successfully treated using chimney graft technique. In 80 patients, the angle between aneurysm neck and suprarenal aorta was measured between 17-90 (mean: 34.9) degrees. In 10 patients, although the angle between aneurysm neck and suprarenal aorta was greater than or equal to 60 degrees, due to increased risk of rupture and surgical mortality risks, the decision was made to treat these patients using endovascular approach and their treatments were successfully completed.

Compared to open surgery, endovascular treatment of AAAs decreases the duration of stay in the intensive care and the hospital, and the need for postoperative mechanical ventilation and blood transfusion.[17,18] When the data from the workgroup "DREAM" were evaluated, it was found that while the mean duration of hospital stay was six days in the group treated using endovascular approach under elective conditions whereas it was 13 days in the group treated using open surgery.[17] In our study, the mean time of discharge from the hospital was fairly short, between 2-24 (mean: 4.54) days, for the 74 patients operated electively. In the data from "United Kingdom EVAR Trial Group" comprising 626 patients treated using endovascular approach due to AAA, perioperative mortality (<30 days) was found to be 1.8%.[19] Again, in the data from "DREAM Trial Group" comprising 171 patients, perioperative mortality (<30 days) was found to be 1.2%.[17] In both studies, we see that perioperative mortality in patients who underwent open surgery is higher than the perioperative mortality in patients who underwent endovascular treatment (perioperative mortality rates for open surgery in the two aforementioned studies are 4.3% and 4.6%, respectively). Similarly, in the meta-analysis of 16 studies, AlOthman et al.[20] demonstrates the superiority of endovascular repair over open surgery in terms of perioperative mortality rates (1.2% *vs.* 4.5%). In our study, perioperative mortality (<30 days) was not observed in any of the 74 patients treated electively and our results were in line with these aforementioned large studies.

In our study, the mean time of discharge was 10 days for cases with ruptured aortic aneurysm. One of the six patients who underwent stent graft implantation due to ruptured AAA was lost five days after the operation and perioperative mortality (<30 days) in the ruptured AAA group was found to be 16.6%. In the study by Veith[21] in which 442 ruptured AAA patients in 48 centers were evaluated, 30-day mortality rate for endovascular treatment was found to be 18%. Again, data from 'United Kingdom National Vascular Database' report that 30-day mortality rate is 29%.[22] Three randomized controlled trial comparing open surgery with endovascular repair for ruptured AAA documented no statistical difference in perioperative mortality (<30 day) between the two therapeutic options.[23-26] In these trials 30 day mortality rates after endovascular repair were between 18-35%. Although the number of patients in our study is less than these studies, our 30-day mortality rate is in line with these data.

Endovascular treatment of aortic aneurysms is one of the most difficult of the endovascular procedures in interventional radiology. The operator must have an adequate experience at endovascular procedures.[4] In addition, preoperative CT angiography is critical in patient selection and the evaluation of patient's suitability for the procedure. In our study, although additional endovascular interventions were required in some patients, success rate for stent graft placement was found to be 100%. None of the patients required conversion to open surgery. In the series by Brewster et al.[27] comprising 873 patients who received endovascular treatment, the rate of conversion to open surgery was 2.32% and the majority of these patients were the cases treated in the initial years of the study. In the same study, the authors attributed this to the selection of unsuitable patients, inadequate experience and the first-generation less flexible stent graft systems with thicker profile. In the study by İşcan et al.[28] in which 187 patients received endovascular treatment, unsuccessful stent placement or conversion to open surgery were not observed in any of the patients.

One of the aim of this paper is to share our experience on intraprocedural unexpected critical events during the endovascular AAA repair. When planning and placing abdominal aortic stent grafts, a number of problems may occur. Endovascular repair of AAAs is not free of adverse events, and it may be necessary to perform concomitant interventions during the procedure. Concomitant interventions can sometimes be considered critical for the success of the procedure; if critical events not adequately corrected there is a high risk of conversion to open surgery or failure. Critical events can be considered as all the problems and technical difficulties that occur during the procedure, which are neither predictable nor foreseen, compromise the success of the treatment and require additional interventions, normally not performed during the routine procedure. These events may involve unplanned coverage of main arteries such as renal artery, injury to the femoral, iliac arteries and abdominal aorta, difficult cannulation of contralateral leg of the main body, problems during the stent-graft delivery or problems with withdrawal of the delivery system. When we examine the literature, Naslund et al.[29] reported a technical complication rate of 26%. Ultee et al.[30] reported that 29% of patients had one or more concomitant procedures during elective endovascular treatment. Likewise, Hobo et al.[31] reported 29% of concomitant procedures during endovascular repair. In the series by Vacirca et al.[32] in which 377 patients received endovascular treatment due to AAA, technical intraoperative complications occurred in 18% of their patients. In our study, concomitant endovascular interventions were required during the procedure in 14 of 81 patients (17.2%). The most common cause of additional intervention (in 5 patients) was the inability to advance the guide wire to the contralateral leg of the main body in order to place the contralateral leg. During the procedure, selective cannulation of the contralateral leg is the critical step for introducing contralateral limb extension and can be sometimes technically very difficult and time-consuming. Also, prolonged contralateral gate cannulation may increase blood loss in ruptured emergency cases. As in our patients, the snare technique can be used if contralateral limb cannulation fails.[8] Fairman et al.[33] described the difficulties while advancing the stent graft delivery system to the aorta as 'access issues' and stated that these situations can be overcome with the 'Brachial-femoral artery access technique', iliac artery/aortic bifurcation balloon angioplasty, and iliofemoral conduits. In our study in two patients main body of the stent graft could not be advanced to the aorta and we overcame this problem by establishing 'axilla-femoral through and through loop'. Proper placement of stent-graft is mandatory for successful outcome after endovascular repair and also for continuity of perfusion via the side branches. The angulated necks are more prone to inaccurate stent graft placement. Renal arteries may be occluded if the stent graft is placed too high. On the other hand, especially in patients with reverse-tapered necks, caudal migration of the stent graft can occur during or immediately after endovascular repair if the stent graft is positioned too low in the proximal neck. This may lead to marked type Ia endoleak. An adequate angulation of the C-arm and detailed analysis of the position of renal arteries are needed to avoid inappropriate stent-graft placement.[8] It's important to note that with an angulated aorta, the best view of the renal arteries and visualization of the fixation zone might not be in a routine anterior-posterior plane, but rather at a more cranial-caudal angle.

In case of need, suprarenal stent graft deployment can be corrected with downward traction using a balloon inflated in the main body of the stent graft or a guidewire crossing the graft bifurcation from one femoral artery to the other. As detailed in the results section we used this problem solving technique (downward traction) in one of our patient successfully. Ultee et al.[30] reported that concomitant procedures performed during endovascular repair are related to increased intraoperative complications as well as postoperative morbidity and mortality. Based on this, especially for procedures performed electively, patients must be carefully chosen, and the need for intervention must be carefully considered.

Conclusion

Evaluation of patients with the suitable imaging methods prior to endovascular treatment of AAAs is critically important for determining the patients' suitability for the procedure and foreseeing additional interventions that might be required during the operation. Clinical studies on endovascular treatment of AAAs suggest that this method is a successful treatment approach. In the coming years, novel developments are expected in the endovascular treatment of AAAs. New-generation stent grafts are expected to decrease postoperative graft-related complications and increase the area of use and durability of stent grafts. In this regard, intermediate- and long-term outcomes of abdominal endovascular treatment with larger series and new stent technologies must be identified.

The results of this study demonstrate that endovascular treatment of AAAs is an approach that may be performed safely with a high technical success rate, and decreases perioperative mortality rate, aneurysm-related mortality rate and time of discharge from the hospital, especially in elderly and high-risk surgical patients. Additional endovascular interventions required in some patients during the operation suggest that endovascular treatment must be performed by experienced teams with extensive knowledge and handle these situations.

Declaration of conflicting interests

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