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Frequency of endoleaks after endovascular treatment of abdominal aortic aneurysm

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Abstract

Nowadays, there are more and more advantages of endovascular treatments for aneurysms of the abdominal aorta compared to open surgical treatment. Endovascular procedure is less invasive and the mortality rate is significantly lower in contrast to open surgical treatment. One of the complications of endovascular treatment of abdominal aortic aneurysm is the occurrence of permeability or endoleak. In this paper, we investigated the frequency and characteristics of endoleaks in patients treated endovascularly for the abdominal aortic aneurysm. Work methods are based on statistical data processing of 60 patients who were treated at the Clinical Department for diagnostic and interventional radiology, University Hospital Split. The data is collected from the archives of the mentioned clinical institute from patients who were treated in the period from January 2016 to May 2019. The analysis revealed that endoleak appeared in 63% of patients. The most common type of endoleak that occurred was endoleak type II. Reintervention related to endoleak was required in 4 patients. In most patients, endoleak type II gradually receded and did not require re-intervention. The average follow-up time of the patients analyzed in this study was 26 months. The average number of controls was 4. Endovascular treatment is a newer method of treatment and constant monitoring of the implanted stent-graft is required.

Keywords: abdominal aortic aneurysm, endovascular treatment, endoleak

Introduction

Aneurysm of the abdominal aorta (AAA) in most cases does not show any symptoms that would indicate that it exists in the body. It is most commonly diagnosed as an incidental finding on ultrasound, indicated for some other reason. Aneurysm rupture is a dangerous and urgent condition that requires a quick reaction. The vast majority of patients with AAA rupture die before arriving at the hospital. In order to avoid rupture of the aneurysm and its complications, it is necessary to treat the aneurysm in a timely manner. AAA treatment is divided into open surgical treatment and endovascular treatment. With the development of medicine, endovascular treatment has more and more advantages compared to surgical treatment. Endovascular treatment is less invasive and the mortality rate is significantly lower compared to open surgical treatment. A possible complication of endovascular treatment of AAA is the formation of an endoleak or permeability. In this paper we will focus on the frequency and characteristics of endoleaks that occur after endovascular treatment and stent-graft implantation. [1]

Abdominal aortic aneurysm (AAA)

Abdominal aortic aneurysm (AAA), abnormal focal dilatation of the abdominal aorta is a life-threatening condition that requires monitoring or treatment depending on the size of the aneurysm and symptomatology. Abdominal aortic aneurysm can be discovered accidentally or at the time of rupture. An arterial aneurysm is defined as a permanent localized dilation of a blood vessel of at least 150% compared with the relative normal adjacent diameter of that artery. [2,3]

Etiology of AAA

Risk factors for AAA include most commonly atherosclerosis, followed by smoking and older age, male gender, Caucasian race, family history of AAA, hypertension,

elevated cholesterol and previous history of aortic dissection. Other causes include cystic medial necrosis, syphilis, HIV and connective tissue disease. People who are not Caucasian and do not have diabetes are considered to have a reduced risk of abdominal aortic aneurysm. In most patients with AAA, progressive expansion is expected, which studies prove. Risk of rupture depends on the size of the aneurysm itself. The rate of increase in diameter for a smaller AAA (3-5 cm) is 0.2 to 0.3 cm in one year and 0.3 to 0.5 cm for aneurysms over 5 cm. Pressure on the aortic wall is proportional to the radius of the aneurysm. For this reason, larger aneurysms are more exposed to risk of rupture, and the presence of hypertension also increases that risk. [1,2,4]

Pathophysiology of AAA

True aneurysms are characterized by dilation of all three layers of the blood vessel wall. Pseudoaneurysms are caused by a interruption of one or more layers of the blood vessel wall. Collagen and elastin are among the main structural elements of the aortic wall. In the infrarenal part of the aorta, the concentration of elastin and collagen is low, and their destruction leads to dilatation of the blood vessel wall. Research has found several proteases in the aortic wall which destroy elastin and/or collagen. The immunological component of the atherosclerotic vascular disease is characterized by infiltration of the aortic wall by T lymphocytes, B lymphocytes and macrophages which activate proteolytic activity. The nature of this response suggests the role of autoimmunity in the pathogenesis of abdominal aortic aneurysm. Recent research has shown that antigen of Chlamydia pneumoniae activates infection in the wall of abdominal aorta. The action of this antigen stimulates proteolytic activity that causes the weakening of the blood vessel wall and the formation of an aneurysm. Inflammatory aneurysms are considered to be at the extreme side of the spectrum of atherosclerotic aneurysms these days and account for 3-10% of all AAA. Non-inflammatory aneurysms differ from inflammatory aneurysms in terms of their clinical presentation and imaging characteristics. The genetic origin of AAA is also known. One or more genes are associated with AAA and atherosclerosis. In high-risk patients, identification of the mentioned genes can make early detection and prevention of AAA easier. Different parts of the aorta are of different embryological origin. Susceptibility to the disease also varies with the fact that the infrarenal abdominal aorta is more prone to atherosclerosis and aneurysm formation than the thoracic aorta. Both the thoracic and abdominal aorta are elastic arteries consisting of the intima, media and adventitia. The aorta, regardless of its location, depends on different fibromuscular layers (so-called lamellar units) to distribute stress and ensure elasticity. Structure of the thoracic aorta consists of approximately 60 units divided into vascular and avascular regions. On the other hand, the abdominal aorta consists of approximately 30 units and is completely avascular. It's probably because of the smaller number of lamellar units and avascular nature, that the abdominal aorta is more prone to aneurysm degenerations. [1,2,4,5]

Clinical presentation of AAA

In most patients, abdominal aortic aneurysms do not cause symptoms and are usually diagnosed as an incidental finding. They are most commonly detected during an ultrasound examination, indicated for some other reason. In a small number of cases aneurysm presents itself by causing symptoms that indicate that it exists in the body. Aneurysm growth can cause symptoms of abdominal organ compression. Due to the floating of the thrombus from the arterial wall, symptoms of peripheral or visceral embolism can occur. In rare cases, back pain may be present, which raises suspicion of aneurysm rupture and requires great caution. Abdominal aortic aneurysm rupture is a life-threatening condition. Patients with ruptured aneurysms are mostly in a state of shock with diffuse abdominal pain and distension. However, the clinical presentation of a ruptured aneurysm in a patient can vary from subtle to quite dramatic. Most patients die before reaching the hospital. During the clinical examination, the patient with rupture may have "tenderness" over the aneurysm or signs of embolization may be present. An aneurysm can rupture into an adjacent cavity or blood vessel and can present as bleeding from the gastrointestinal tract. When processing the patient, it is necessary to search for other associated aneurysms. The most common associated aneurysm is an iliac artery aneurysm. Associated peripheral aneurysms are present in 5% of patients. The most common associated peripheral aneurysm is an aneurysm of the popliteal arteries. [1,2,4,6]

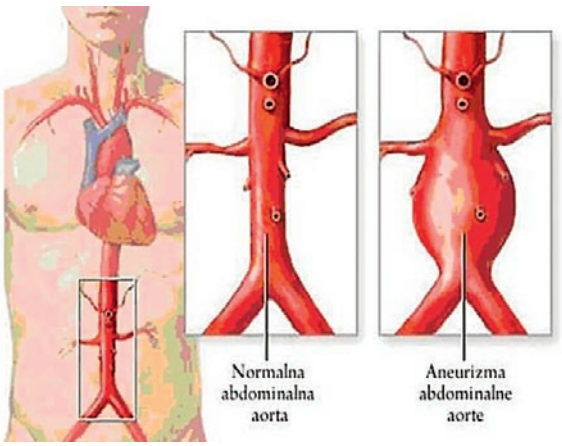


Figure 1. View of normal abdominal aorta and pathologically changed aorta.
Source: https://www.krenizdravo.hr/zdravlje/bolesti-zdravlje/aneurizma-abdominalne-aorte-uzroci-i-lijecenje

Endoleak

Endoleak is a special term used to define the permeability of blood flow outside the lumen of an endovascularly placed stent-graft into the aneurysmal sac or adjacent vascular structure. An endoleak is classified according to the presumed site of blood flow permeability. We distinguish four types of endoleaks. These are endoleak type I, endoleak type II, endoleak type III and endoleak type IV. Endoleak type I occurs when blood leaks at the

proximal or distal end. This type usually occurs during the intervention itself and is often called an early endoleak type I. However, it can also occur later if the blood passes through a blood clot located at the point of stent-graft fixation to the aortic wall. A type II endoleak occurs when a retrograde arterial vessel fills the aneurysmal sac. In case of retrograde blood flow continuous circulation can exist inside the aneurysmal sac. Endoleak type III occurs when the body of the stent graft is inadequately or insufficiently connected to the contralateral iliac limb or in the case of inadequate connection of the main stent-graft with the later placed proximal or distal extensions. This type of endoleak can also be caused by a rupture of the graft material and most often occurs during the EVAR intervention due to technical difficulties and is called an early endoleak type III. Endoleak type III can also occur later when stent-graft displacement or extension occurs as a result of aneurysm retraction or as a consequence of material fatigue and stent rupture, which can lead to graft rupture. Flows created by these mechanisms are called late endoleak type III. Endoleak type IV occurs due to the porosity of the material and the passage of blood through the stent-graft. Initial blood flow through the graft always exists if it has not been processed during production to cause the formation of clots inside its pores. By generating ever thinner graft materials, this type of endoleak is becoming more common. There is a subgroup of patients in whom dilatation of the aneurysmal sac occurs but there is no defined leak source. This subgroup is labeled endoleak type V and can be a consequence of a phenomenon called endotension, in which the pressure in the sac increases despite unidentified state. Endotension is a special condition associated with EVAR in which there

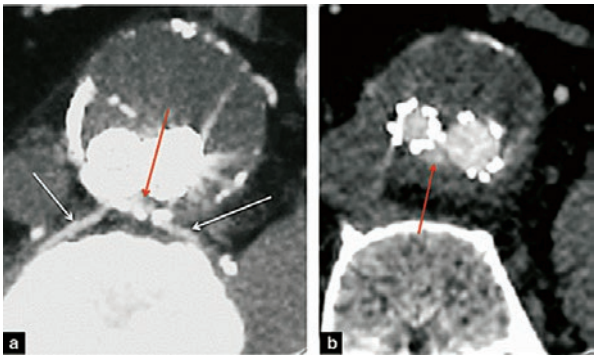


Figure 2. Presentation of endoleak
Izvor: Sriharsha Gummadi, John R Eisenbrey, Andrej Lyshchik; A nararative review on contrast – enhanced ultrasound in aortic endograft endoleak survillance; Ultrasound Q. 2018 sep; 34(3):170-175 doi: 10.1097/RUQ.0000000000000353

is an increase in pressure inside the aneurysm while there are no signs of flow outside the graft. It is considered that the most likely mechanism of this condition is the transfer of pressure through the thrombus at the anchoring site of the stent-graft. Since blood leaks in aneurysms are often asymptomatic and early recognition can enable repair with minimally invasive intervention, society of vascular surgery recommends lifelong surveillance. The gold standard recommended by the society of vascular surgery is CTA with 3D reconstruction 1 month after surgery and then once per year. If an abnormality is noted on the initial postoperative imaging, another examination is recommended after 6 months. The Society of Vascular Surgery is aware of cost, nephrotoxicity, and radiation exposure concerns with lifelong CT imaging and suggests

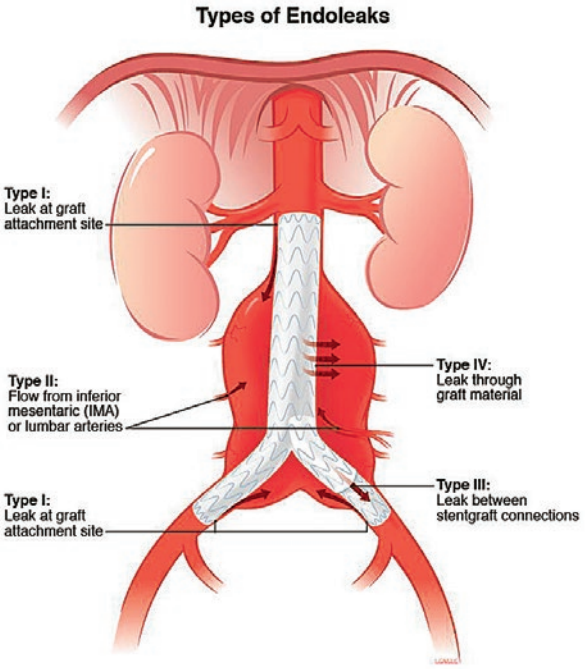


Figure 3. Presentation of type II endoleak on CT
Source: L. Cassagnes, R. Perignon, F. Amokrane, A. Petermann, T. Becaud, B. Saint-Lebes, P. Chabrot, H. Rousseau, L. Boyer; Aortic stent-grafts: Endoleak surveillance; Diagnostic and Interventional Imaging; Volume 97, Issues 1, January 2016, pages 19-27

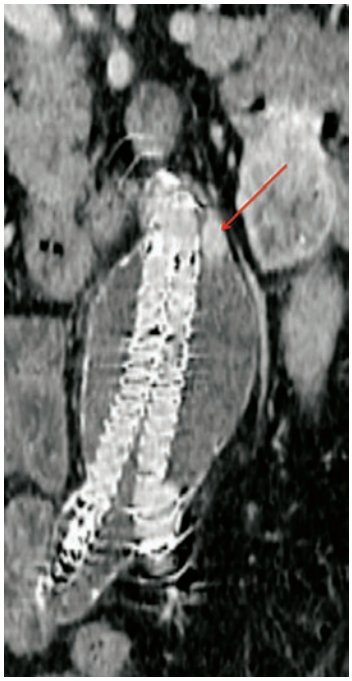


Figure 4. CT image of a large leakage – endoleak type I
Source: L. Cassagnes, R. Perignon, F. Amokrane, A. Petermann, T. Becaud, B. Saint-Lebes, P. Chabrot, H. Rousseau, L. Boyer; Aortic stent-grafts: Endoleak surveillance; Diagnostic and Interventional Imaging; Volume 97, Issues 1, January 2016, pages 19-27

that color ultrasound could replace CTA if they are no detected abnormalities in the first year and in patients with contraindications for CTA. However, color ultrasound is less sensitive than CTA, failing to detect as many as 31% of endopermeability cases. By development of ultrasound methods and the implementation of subsequent meta-analyses as well as systematic examinations, the diagnostic accuracy of ultrasound was compared with CT in detection of endopermeability. The European Federation of Society for Ultrasound in Medicine and Biology suggests that the early results are promising and ultrasound may be suitable for characterization of endopermeability. [7,8,9,10,11]

Methods

The test methods are based on statistical data processing of 60 patients diagnosed withaneurysms of the abdominal aorta, who were treated with an endovascular approach at the Clinical Department for diagnostic and interventional radiology, University Hospital Split. The analysis is performed on the basis of data obtained from the archives of the Clinical Department for diagnostic and interventional radiology, University Hospital Split. The data was collected from patients who were treated in the period from January 2016 to May 2019. Of the 85 performed EVAR procedures in that period, the analysis was performed in 60 EVARs that had more controls after the procedure.

Goal

The aim of this paper is to determine how often endoleaks occur after endovascular surgery treatment of abdominal aortic aneurysm. Then, to determine which type of endoleak is the most common, show the occurence of endoleaks during the period of control and to determine how often reintervention occurs. The goal is also to determine the average number of controls and the average follow-up period after EVAR in the patients analyzed in this paper.

The results

The results show the patients divided by gender. The analysis found that more men (88%) were treated for abdominal aortic aneurysm than women (12%). Endoleaks were present in 63% of patients, while endoleak did not appear in 37% of patients. Results regarding the occurrences of endoleaks are shown in table 2 and 3.

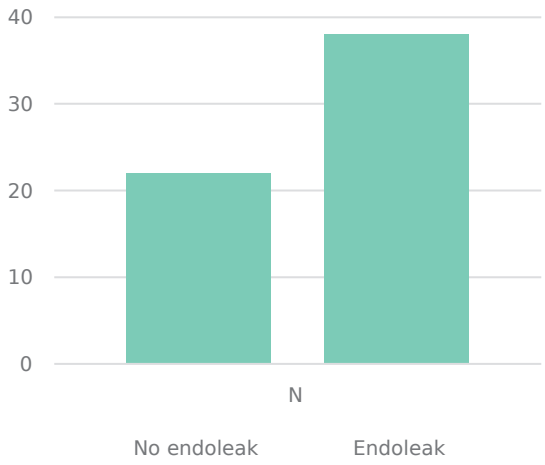
Table 1. Presentation of patients by gender.

SEX	N	%
Men	53	88
Women	7	12
TOTAL	**60**	**100**

Table 2. Presentation of patients with endoleak and without endoleak after endovascular treatment of abdominal aortic aneurysms

	N	%
ENDOLEAK	38	63
NO ENDOLEAK	22	37
TOTAL	**60**	**100**

Table 3. Graphic presentation of patients with endoleak and without endoleak after endovascular treatment of abdominal aortic aneurysm



The most common type of endoleak that occurred in patients with an endoleak (28 patients) is endoleak type II (74%). Type II endoleak is followed by type IV endoleak (26%), then endoleak type I (21%) and endoleak type III (3%). Results on the most common types of endoleaks are described in Tables 4 and 5. It is important to emphasize that some patients had more than one type of endoleak (table 6,7).

Table 4. Presentation of the most common type of endoleak in patients treated for aneurysm of abdominal aorta using endovascular method

TYPE OF ENDOLEAK	N	%
Endoleak type I	8	21
Endoleak type II	28	74
Endoleak type III	1	3
Endoleak type IV	10	26

Table 5. Graphic presentation of the most common type of endoleak in patients treated for aneurysm of abdominal aorta by endovascular method

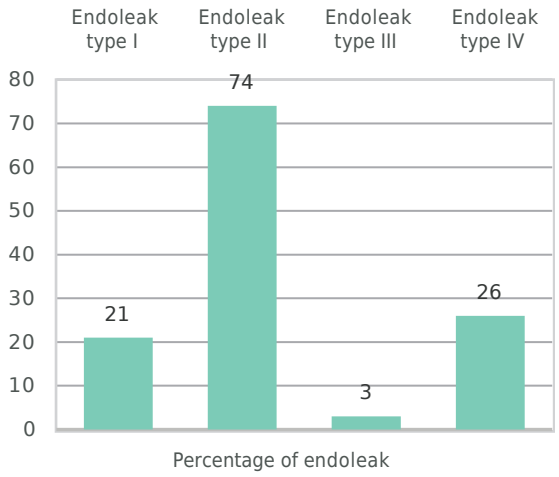
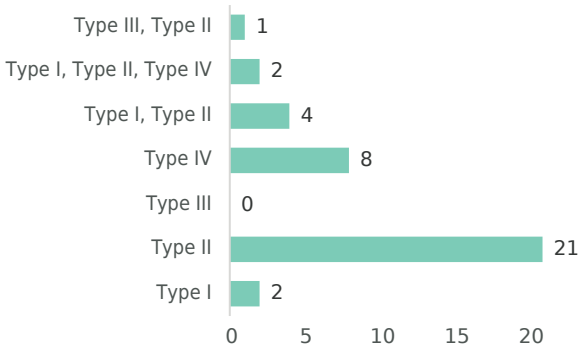


Table 6. Presentation of patients in whom only one type of endoleak appeared and patients in which several types of endoleaks appeared

TYPE OF ENDOLEAK	N
Type I	2
Type II	21
Type III	0
Type IV	8
Type I, Type II	4
Type I, Type II, Type IV	2
Type III, Type II	1
TOTAL:	**38**

Table 7. Graphic presentation of patients with only one type of endoleak and patients with multiple types of endoleaks

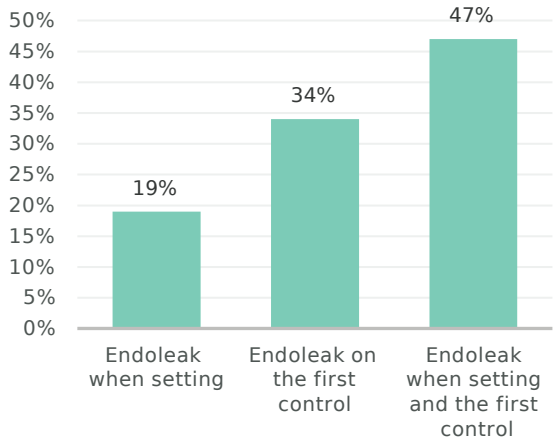


Tables 8 and 9 show the time at which the endoleak appeared in relation to the first control and when placing a stent-graft. Endoleaks appeared only during placement in 19% of patients. The appearance of endoleaks at the first check-up was recorded in 34% of patients. The presence of endoleaks at the time of placement and at the first check-up was observed in 47% of patients.

Table 8. Presentation of data on the time of appearance of endoleak in relation to the first control and when placing a stent-graft

	N	%
Endoleak when setting	7	19
Endoleak on the first control	13	34
Endoleak when setting and the first control	18	47
TOTAL	**38**	**100**

Table 9. Graphic presentation of data on the time of appearance of endoleaks in relation to first control and placing a stent-graft



The most common type of endoleak that occurred in the group of patients who had an endoleak only during placement was endoleak type II (57%). In a fairly high percentage of cases we found endoleak type IV as well (43%). The most common type of endoleak in patients with endoleak reported at the first control (MSCT after 48 h) was also endoleak type II (78%). The afformentioned data is shown in tables 10,11,12.

Table 10. Presentation of the most common type of endoleak in patients who had an endoleak only during stent-graft placement and the most common type of endoleak in patients with endoleak at the first control

	Type of endoleak	N	%
Endoleak when setting	TYPE IV	3	43
	TYPE II	4	57
	Type of endoleaka	**N**	**%**
Endoleak on the first control	TYPE I	1	8
	TYPE II	10	77
	TYPE III	1	8
	TYPE IV	3	23

Table 11. Presentation of the most common type of endoleak in patients who had an endoleak only at the time of placement

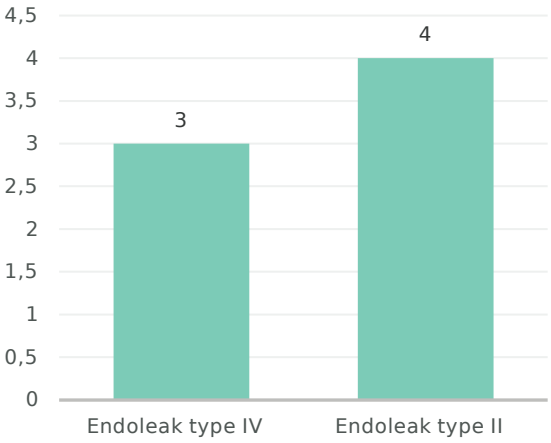
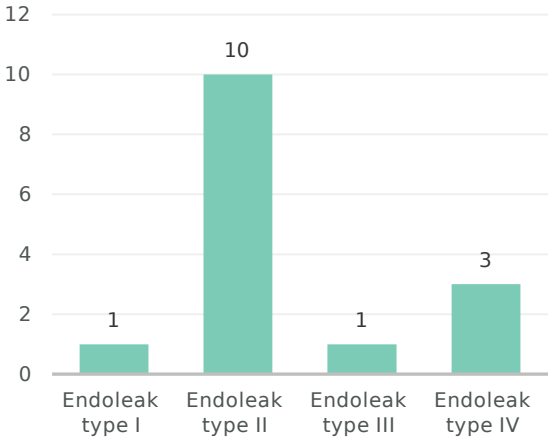
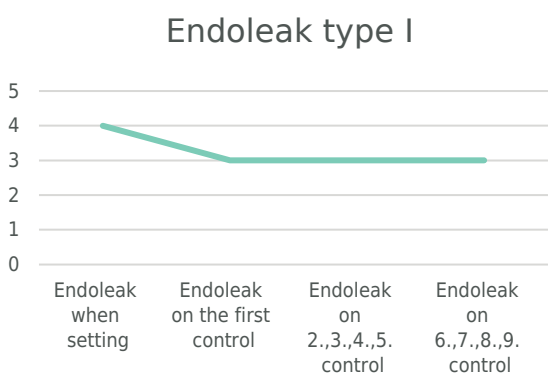


Table 12. Presentation of the most common type of endoleak in patients who had an endoleak during the first control



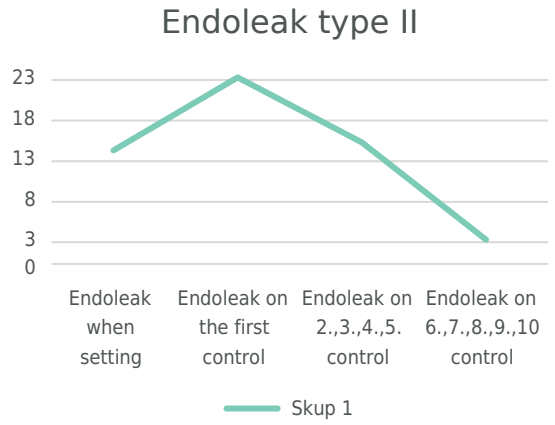
During the follow up period we observed that the endoleak type I was most common at the time of placement. Its occurence was in a slight decline at the first control, then at further controls was constant. From this data we can conclude that endoleak type I generally does not resolve on its own, reintervention is required to remove the endoleak (Table 13).

Table 13. Graphic representation of the occurrence of type I endoleaks during the follow up period



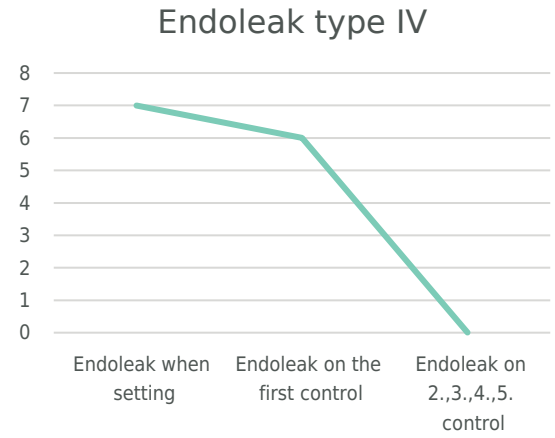
The highest incidence of type II endoleaks was present at the first controls. On further controls, the occurrence of endoleaks was in a significant decline, which means that endoleak type II gradually withdrew. This data speaks in favor of the fact that endoleak type II in most cases does not require treatment (table 14).

Table 14. Graphic representation of the occurrence of type II endoleaks during the follow up period



Regarding the occurrence of endoleak type IV throughout the follow-up period, the highest occurrence was in time of placement, after the first control there is a big drop and at the further controls it is almost absent (table 15).

Table 15. Graphic representation of the occurence of type IV endoleaks during the follow up period



Repeat intervention was performed in 10 patients (17%). Reintervention due to occurrence of endoleak was performed in 40% of patients compared to all reinterventions. Most often, additional extension of the implanted stent-graft was performed. Reintervention because of some other cause was performed in 60% of patients. The most common other cause of reintervention is stent graft occlusion and stent graft stenosis (table 16,17,18). On average, 4 controls were performed per patient. The average follow-up time for patients was 26 months (table 19,20).

Table 16. Presentation of patients who underwent reintervention after endovascular treatment of abdominal aortic aneurysm

	N	%
Reintervention related to endoleak	4	40
Reintervention related to another cause	6	60
TOTAL	**10**	**100**

Table 17. Presentation of data on reintervention in patients with reintervention associated with endoleak

Type of reintervention	Type of endoleak	N
Extension	Type I, Type II	3
Implatantion of coil in the III. lumbar artery	Type II	1

Table 18. Presentation of data on reintervention in patients with reintervention not associated with an endoleak

Type of reintervention	Cause of reintervention	N
Thrombolysis, thromboembolectomy, stenting	Stent-graft occlusion, stenosis	5
Surgical treatment, placement of a surgical stent-graft	Aneurysm rupture	1

Table 19. Presentation of controls in patients treated for abdominal aortic aneurysm using endovascular method

Controls	N
1	6
2	13
3	11
4	8
5	7
6	8
7	2
8	1
9	2
10	2
TOTAL	**60**

Average control per patient: 4 control

Table 20. Presentation of the follow up period for patients treated for abdominal aortic aneurysm using endovascular method

Monitoring period (in months)	N		Monitoring period (in months)	N
1	9		30	1
3	2		34	1
4	1		35	1
5	1		36	8
6	1		38	2
7	1		41	1
8	1		42	1
9	1		44	1
13	1		47	1
17	2		48	1
18	2		50	1
19	1		51	1
20	3		52	1
21	2		54	1
22	1		56	1
24	4		60	1
28	1		61	2

Average patient follow up time ≈ 26 months

Discussion

Aneurysm of the abdominal aorta is nowadays increasingly diagnosed as an incidental finding and most often on an ultrasound that is indicated for some other reason. In this paper we have seen that a greater number of men were treated for AAA using the endovascular method than women. This claim agrees with other studies in which the occurrence of AAA is described in the largest number in Caucasians males. Monitoring the condition after EVAR is extremely important because the occurrence of endoleaks usually happens without symptoms. From the results of this study, we have seen that the occurrence of endoleaks can be quite frequent.

Endoleak occurence depends on many factors. Before the procedure itself, it is necessary to do a detail diagnostic processing in order to obtain an accurate representation of the aneurysm and its surroundings and thereby conclude whether that patient is suitable for endovascular treatment. The occurence of endoleaks can also depend on the choice of stent-graft and the very quality of that stent-graft. Proper placement technique is also important, which depends on the experience and knowledge of the operator. The most common type of endoleak that occurs is endoleak type II, which is also described in the vast majority of other studies. Endoleak type II can cause increased pressure and, as a result, rupture of the

aneurysmal sac. However, more and more research, as well as this paper, indicate that most aneurysms with endoleak type II remain stable or will decrease in size due to slow flow and spontaneous thrombosis.

From the above we can conclude that most type II endoleaks, especially the smaller ones, do not require treatment. Endovascular treatment is a newer method of treatment. The disadvantage of endovascular treatment is the need for constant monitoring of the state of the stent-graft in the body. Some patients analyzed in this paper have a shorter follow-up period, which can be a disadvantage for obtaining objective study results. [2,3,6]

Conclusion

In this study, we analyzed a group of 60 patients with a diagnosis of abdominal aortic aneurysm, who were treated using the endovascular method of a stent-graft implantation. Results are based on data obtained from the archives of the Clinical Department for diagnostic and interventional radiology, University Hospital Split. We used data from patients treated in the period from January 2016 to May 2019. The analysis determined that the treatment of aneurysm of the abdominal aorta using the endovascular method was performed more often in men (88%) than in women (12%). Endoleaks appeared in 63% of patients, while 37% of patients did not develop an endoleak. The most common type of endoleak that occurred in patients is endoleak type II (74%). Some patients experienced several types of endoleaks. 19% of patients had the occurence of endoleaks only during placement, 34% at the first check-up and 47% of patients had it during placement and at the first check-up. Endoleak type II is the most common type of endoleak to appear only during placement (57%), as well as the most common type of endoleak to appear at the first control (77%). During the follow up period we observed that the endoleak type I was most common at the time of placement. Its occurence was in a slight decline at the first control, then at further controls was constant.

The highest incidence of type II endoleaks was present at the first controls. On further controls, the occurrence of endoleaks was in a significant decline, which means that endoleak type II gradually withdrew. Endoleak type IV was most often seen during placement and was almost absent on the subsequent controls. In 17% of patients reintervention occurred. Reintervention related to endoleak was present in 40% patients. The average number of controls was 4. Average follow-up time of patients was 26 months. ■

Literature

1. Josip Mašković, Stipan janković; Selected chapters of interventional radiology; textbooks of the University in Split, Faculty of Medicine; 2008 godina izdavanja
2. Palma M. Shaw, John Loree, Ryan C. Gibbons; Abdominal Aortic Aneurysm; StatPearls, Jan, 2021; PMID: 29262134; ID: NBK470237
3. Ryoko Umebayashi, Haruhito A. Uchida, Jun Wada; Abdominal aortic aneurysm in aged population; Aging (Albany NY), 2018 Dec 6; 10(12):3650-3651 doi: 10.18632/aging.101702
4. Sourabh Aggarwal, Arman Qamar, Vishal Sharma, Alka Sharma; Abdominal aortic aneurysm: A comprehensive review; Experimental & Clinical cardiology; Spring 2011;16(1):11-5
5. Helena Kuivaniemi, Evan J Ryer, James R Elmore, Gerard Tromp; Understanding the pathogenesis of abdominal aortic aneurysm; Expert Rev Cardiovasc Ther. 2015; 13(9):975-987
6. Brian Keisler, Chuck Carter; Abdominal aortic anwurysm; Am Fam Physician; 2015 Apr 15;91(8):538-543
7. Sriharsha Gummadi, John R Eisenbrey, Andrej Lyshchik; A nararative review on contrast – enhanced ultrasound in aortic endograft endoleak survillance; Ultrasound Q. 2018 sep; 34(3):170-175 doi: 10.1097/RUQ.0000000000000353
8. Aman Berry Williams, Zoheb Berry Williams; Imaging modalities for endoleak surveillance; Journal of Medical Radiation Sciences; 2021 jun 18. doi: 10.1002/jmrs.522
9. Brian G Derubertis, Susan M Trocciola, Evan J Ryer, Fred M Pieracci; Abdominal aortic aneurysm in women: prevlence, risk factors and implacations for screening; Journal of Vascular Surgery 2007 Oct ;46(4):630-635 doi: 10.1016/j.jvs.2007.06.024.
10. Jacgues Cornuz, Claudio Sidoti Pinto, Heindrik Tevaearai, Matthias Egger; Risk factors for asymptomatic abdominal aortic aneurysm: systematic review and meta-analysis of population-based screening studies; European Journal of public health; 2004 Dec; 14(4):343-9. doi: 10.1093/europub/14.4.343.
11. Anand Shah, S. William Stavropoulos; Imaging Surveillance following Endovascular Aneurysm Repair; Seminars in Interventional Radiology; 2009 Mar; 26(1): 10-16 doi: 10.1055/s-0029-1208378
12. A. Chavan, T.U. Cohnert, J. Heine, C. Dresler, M. Leuwer, W. Harringer, M. Jorgensen, A. Haverich, M. Galanski; Endoluminal grafting of abdominal aortic aneurysms: experience with the Talent endoluminal stent graft; European Radiology 10(4):634-641 March 2000; doi: 10.1007/s003300050976
13. Ruth A Benson, Lewis Meecham, Owain Fisher, Ian M Loftus; Ultrasound screening for abdominal aortic aneurysm: current practice, challenges and controversies; Br J Radiol. 2018 Oct;91(1091):20170306 doi: 10.1259/bjr.20170306