

# Respiratory Rehabilitation in Patients with Abdominal Aortic Aneurysm Submitted to OPEN and EVAR Treatment: Predictive Factors of Post-operative Pulmonary Complications and Clinical Implications

Andrea Ascoli Marchetti<sup>1\*</sup>, Gianluca Citoni<sup>1</sup>, Calogero Foti<sup>2</sup>, Arnaldo Ippoliti<sup>1</sup>

<sup>1</sup>Vascular Surgery, Biomedicine and Prevention Department, University of Rome, Tor Vergata, Rome, Italy; <sup>2</sup>Physical Medicine and Rehabilitation, Department of Clinical Sciences and Translational Medicine, University of Rome Tor Vergata, Rome, Italy

## ABSTRACT

**Background:** In the conventional surgical treatment of aneurysms, the respiratory physiotherapy is one of the cornerstones of patient rehabilitation. The endovascular technique, with less invasiveness, has significantly changed the rehabilitative approach to the operated subject.

**Objective of the study:** to evaluate and compare the effectiveness of the pre and post-operative rehabilitation treatment associated with the conventional OPEN surgery compared to the EVAR procedure and their incidence in preventing postoperative respiratory complications.

**Design:** Longitudinal case control study to compare patients who have open surgery with patients who do not have the laparotomy, as in ENDO technique, to look how frequently the postoperative pneumonia and the risk factor was present in each group to determine the relationship between the risk factor, the type of operation and the pneumonia incidence.

**Setting** Data were collected from patients admitted consecutively at the Tor Vergata Hospital with diagnosis of an abdominal aortic aneurysm. Risk factors, type of intervention, pneumonia incidence in postoperative period was evaluated at 30 days.

**Population:** Three hundred and twenty patient were enrolled.

**Materials and methods:** From 2005 to 2016, 320 patients suffering from an abdominal aortic aneurysm were treated consecutively. One hundred eighty one patients were treated using the open technique (group A) and 139 using the EVAR technique (group B). All patients in OPEN group were submitted to respiratory rehabilitation protocol. Risk factors, type of intervention, anesthesia and results of treatment with complications, observed mortality, mean hospital stay were studied. Pre and postoperative respiratory rehabilitation treatment protocol was performed in all of the patients. The data were analyzed with descriptive statistics and inferential statistics using SPSS 18.0 for Windows.

**Results:** From 2005-2010, the postoperative stay (days) was significant shorter for EVAR compared to open (6.47 vs. 10.48; P 0.001). From 2011-2016, the postoperative stay (days) was significant shorter EVAR compared open (4.07 vs. 11.41; P 0.001). The patients treated from 2011 to 2016 for both OPEN and EVAR groups presented an average age 3 years lower compared to the patients treated in the period from 2005-2011 (75.5 to 72.8 for EVAR and from 71,2 to 68,2). The patients treated from 2011 to 2016 for EVAR group presented an average reduction in post-operative hospitalization of 2.4 days (-37.09%) compared to 2005-2011 period. There was a significant higher incidence of pneumonia in the open group (P=0.001). The reduction of the incidence of pneumonia in group A and B during the two different periods from 2005 to 2010 and from 2011 to 2016 was observed. There wasn't a significant difference in the incidence of pneumonia in patients treated from 2005 to 2010

\*Correspondence to: Andrea Ascoli Marchetti, Vascular Surgery, Biomedicine and Prevention Department, University of Rome, Tor Vergata, Rome, Italy, Tel: 00393397731745; E-mail: ascolimarchetti@med.uniroma2.it

Received: March 25, 2020; Accepted: April 09, 2020; Published: April 16, 2020

Citation: Ascoli Marchetti A, Citoni G, Foti C, Ippoliti A (2020) Respiratory Rehabilitation in Patients with Abdominal Aortic aneurysm submitted to OPEN and EVAR Treatment: Predictive factors of Post-operative Pulmonary Complications and Clinical Implications. J Vasc Med Surg 8:3. doi: 10.35248/2329-6925.20.8.390.

Copyright: © 2020 Ascoli Marchetti A, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

(P-value=0.1). In patients treated from 2011 to 2016 there was a significant increasing the incidence of pneumonia in OPEN group (P=0.001).

**Conclusion:** Rehabilitation physiotherapy plays a fundamental role in the prevention of postoperative complications of patients undergoing OPEN treatment. Despite of the excellent results obtained in patients undergoing OPEN treatment, the lower rate of complications in EVAR group showed better results of this treatment.

**Keywords:** Abdominal aortic aneurysm; Open treatment; EVAR treatment; Prevention; Post-operative complications; Respiratory complications; Rehabilitation; Respiratory exercise

## INTRODUCTION

OPEN treatment of aneurysms of the abdominal infrarenal aorta has good immediate and late results [1-4]. Pre and post-operative rehabilitation treatment has a decisive role in the prevention of respiratory complications because abdominal surgery causes an important alteration of respiratory physiology. The preoperative phase is necessary to train the patient for ventilation exercises that he will have to perform autonomously in the postoperative period. The main culprits of perioperative and postoperative respiratory disorders are laparotomy, surgical incision and anesthesia [5-12]. The use of anesthetic drugs during surgery cause the depression of the respiratory centers, the onset of bronchial spasms, a decrease in bronchial activity and a reactive hyper secretion. The surgical incision, instead, has very important effects on the ventilatory function; therefore, it depends on the location, the route and the length of the incision. The surgical act involves the reduction of the lung volumes, above all of the vital capacity and, to a lesser extent, of the residual lung capacity. Furthermore, it induces modifications of the thoracoabdominal movements: involving the abdominal muscles, the incision modifies the expiratory kinetics of the diaphragm and alters the synergy of the transverse diaphragm couple determining a basal hypoventilation, in addition to the pain related to the deep inspiration [13]. The introduction of the EVAR procedure, with an access route that does not compromise the respiratory dynamics in the postoperative period, reduce postoperative morbidity and hospitalization length [14]. The aim of this work is to evaluate the predictive factors of respiratory complications associated with the traditional OPEN and EVAR method and the influence of rehabilitation protocol in the prevention and treatment of postoperative complications.

## MATERIALS AND METHODS

From 2005 to 2016, 320 patients suffering from an abdominal aortic aneurysm were treated consecutively. One hundred eighty one patients were treated using the open technique (group A) and 139 using the EVAR technique (group B). All patients in OPEN group were submitted to respiratory rehabilitation protocol. A further subdivision of groups A and B was then made based on the period during which the intervention was performed: respectively between 2005 and 2010; and between 2011 and 2016. Cardiovascular risk factors were evaluated: smoking, COPD, diabetes mellitus, chronic renal failure, arterial hypertension, dyslipidemia, ischemic heart disease, chronic obstructive artery and immediate results in the two groups. All patients treated in group A underwent pre-operative and post-operative training by means of sessions lasting 30 minutes, according to the physiotherapy protocol adopted at our Teaching Hospital. Treatment protocol of perioperative-operative physiotherapy. Role of respiratory rehabilitation and rehabilitation protocol. Inspiratory muscle training during the preoperative training phase and the application of an adequate postoperative rehabilitation protocol

play an important role in reducing the incidence of postoperative respiratory complications in patients undergoing OPEN treatment. Among the goals of physiotherapy treatment it is important to pay particular attention to counteracting the effects caused by surgery on respiratory function, through breathing exercises and lung re-expansion aimed at facilitating mucociliary clearance and preventing the formation of atelectasis, considered as one of the subclinical signs more predisposing to the onset of pneumonia, the main object of our study.

The following is the rehabilitation protocol after abdominal surgery for AAA. Treatment should start early, immediately after surgery. The sessions will be brief and frequent. The physiotherapist has the task of changing the patient's position and adopting, on the first day, an early mobilization limiting, as far as possible, only the supine decubitus.

1st Day-During the session the oximetry is monitored maintaining saturation above 90-92%, eventually using or increasing the oxygen therapy and controlling post-surgical pain that could compromise the compliance of the treatment. The following key point are essential: Thoracic breathing (TEE technique), Use of spirometric incentives, Cough education. After the surgeon's consent, the patient can adopt an upright position after wearing a containing abdominal band, necessary to protect and contain the abdominal expansion.

A self-treatment program is set up:

- To favor the restoration of a balanced and symmetrical cost-diaphragmatic kinetics (prudent solicitation of upper and lower costal expansions in supine or sitting decubitus position).
- To avoid stiffness or reduction of muscle strength (work mainly on the scapula fixators: latissimus dorsi muscle, granulated tooth, rhomboid muscle and trapezius, active-assisted kinesitherapy of the cervico/dorso/lumbar spine). Education for family members (when deemed necessary).

2<sup>nd</sup> and 3<sup>rd</sup> Day-exercises with TEE and BC technique. In the presence of secretions, assisted cough techniques are performed. Passive and active exercises for the shoulder girdle, for the AASS (upper limbs) and AAIL (lower limbs), for the head and neck.

4<sup>th</sup> and 5<sup>th</sup> Day-Contraction of the abdominal muscles. Exercises are performed in a sitting position of muscular reinforcement for the lower limbs and, subsequently, re-education to the march.

From 6<sup>th</sup> Day - proceed as in the fifth, making the patient responsible, who will have to perform all the exercises several times a day. Global physical re-education exercises and adaptation to effort are started. Ultimately the validity of this protocol contributes significantly to the success of the intervention. In fact, it is necessary to consider that, even if there is less use of traditional surgery, it is imperative to pay adequate attention to physiotherapy

in patients to be treated with OPEN, since the role of prevention of postoperative complications is undisputed.

## STATISTICAL ANALYSIS AND DATA COLLECTION

The clinical records of the patients affected by aortic abdominal aneurysm and treated using open or EVAR procedures at the University Teaching Hospital were collected and analyzed. The research project aims to explore and demonstrate the relationships between these types of intervention and post-operative complications, particularly respiratory ones, to verify possible correlations. In order to declare the statistical evidence and significance, the expected value of the p-value must be equal to  $\alpha \leq 0.05$  ( $\alpha \leq 0.05$ ). The demographic variables, risk factors, comorbidities and immediate results in the two groups were studied. Where possible, the respiratory parameters FEV-1 and FVC and the preoperative ventilatory deficit of treated patients were considered. Three ad hoc tables have been created to relate the type of intervention (EVAR, OPEN), and the positivity or otherwise to the pneumonia factor. From the data entered we were able to extrapolate the odd ratio, variance, gauss distribution parameters and finally the P-value, a value that in a hypothesis test indicates the probability of obtaining an equal result or "more extreme" of the one observed, assuming the null hypothesis to be true. It is also called the observed significance level.

## RESULTS

The Tables 1 and 2 showed the risk factors of the EVAR and OPEN group, during the two analyzed period. In red, we have highlighted the statistically significant data.

Tables 3 and 4 reveal data regarding the age of the patients, the

**Table 1:** Risk factors in the period 2005/2010: EVAR e OPEN treatment.

Risk factors ('05-'10)	EVAR (%)	OPEN (%)	P value
Nicotine abuse	72	70,861	0.48
COPD	41	35,099	0.001
Diabetes mellitus	18	15,894	0.001
Hypertension	83	87,417	0.001
Dyslipidemia	53	42,384	0.001
Ischemic heart disease	33	26,490	0.001
PAD	15	13,907	0.001
Postoperative complications	24	25,166	0.20

**Table 2:** Risk factors in the period 2011/2016: EVAR e OPEN treatment.

Risk factors ('11-'16)	EVAR (%)	OPEN (%)	P value
Nicotine abuse (si)	75,170	46,667	0,02
COPD (si)	46,259	30,000	0,01
Insufficienza renale cronica (si)	9,184	13,333	0,02
Diabetes mellitus (si)	9,864	13,333	0,06
Hypertension	92,517	80,000	0,03
Dyslipidemia (si)	62,585	36,667	0,02
Ischemic heart disease (si)(si)	38,435	16,667	0,05
PAD (si)	17,007	23,333	0,06
Postoperative complications si)	11,628	26,667	1
Ischemic heart disease (si)(si)	38,435	16,667	0,05
PAD (si)	17,007	23,333	0,06
Postoperative complications si)	11,628	26,667	1

diameter of the aneurysm and the duration of postoperative hospitalization during the two analyzed period. From 2005-2010, the postoperative stay (days) was significant shorter for EVAR compared to open (6.47 vs. 10.48; P 0.001). From 2011-2016, the postoperative stay (days) was significant shorter EVAR compared open (4.07 vs. 11.41; P 0.001). The patients treated from 2011 to 2016 for both OPEN and EVAR groups presented an average age 3 years lower compared to the patients treated in the period from 2005-2011 (75.5 to 72.8 for EVAR and from 71,2 to 68,2).

The patients treated from 2011 to 2016 for EVAR group presented an average reduction in post-operative hospitalization of 2.4 days (-37.09%) compared to 2005-2011 period.

Table 5 shows the results of the interaction between the technique used for the intervention and the incidence of respiratory complications: group A represent patients treated with the OPEN technique and group B those treated with the EVAR technique. This table show a significant higher incidence of pneumonia in the open group (P=0.001).

**Table 3:** Demographic and laboratory data. Period 2005/2010: EVAR e OPEN treatment.

Patients '05-'10	EVAR	OPEN	Pvalue
Age (years)	75,5	71,27	0.001
dtm- (mm)	55.1	59.9	0.003
C-reactive protein	6,18	12,79	0.005
ESR pre-op	22	23,72	0.80
postoperative hospitalization (day)	6,47	10,48	0.001

**Table 4:** Demographic and laboratory data. Period 2011/2016: EVAR e OPEN

Patients '11-'16	EVAR	OPEN	Pvalue
Age (Years)	72,8	68,2	0.03
DTM (mm)	53.725	61,68	0.21
C-reactive protein	6,2	22,37	0.02
ERS pre-op	37,7	33,4	0.38
postoperative hospitalization (day)	4,07	11,41	0.001

**Table 5:** Pneumonia incidence: Period 2005/2016. EVAR e OPEN treatment comparison.

2005-2016	EVAR	%	OPEN	%	TOTALE	%	Pvalue
Pneumonia Yes	2	1,44	22	12,15	24	8,14	
Pneumonia NO	137	98,56	15v8	87,85	295	91,86	
Overall patients	139		180		319		0,001

**Table 6:** Pneumonia incidence: Period 2005/2010. EVAR e OPEN treatment comparison.

2005-2010	EVAR	%	OPEN	%	TOTALE	%	Pvalue
Pneumonia Yes	2	2,08	9	6,34	11	4,66	
Pneumonia NO	94	97,62	142	93,66	236	95,34	
Overall patients	96		151		151		0,1

**Table 7:** Pneumonia incidence: Period 2011/2016. EVAR e OPEN treatment comparison.

2011-2016	EVAR	%	OPEN	%	TOTALE	%	Pvalue
Pneumonia Yes	1	2,27	13	52,94	14	23,33	
Pneumonia NO	43	97,73	17	47,06	60	76,67	
Overall patients	44		30		74		0,001

**Table 8:** Pneumonia incidence: Period 2005/2016. EVAR e OPEN treatment comparison.

2005-2016	EVAR	%	OPEN	%	TOTALE	%	Pvalue
Pneumonia Yes	2	1,44	22	12,15	24	8,14	
Pneumonia No	137	98,56	158	87,85	295	91,86	
Overall patients	139		180		319		0,001

In Tables 6 and 7 are described the incidence of pneumonia in group A and B during the two different periods from 2005 to 2010 (Table 6) and from 2011 to 2016 (Table 7). There wasn't a significant difference in the incidence of pneumonia in patients treated from 2005 to 2010 (P-value=0.1), (tab VI). In patients treated from 2011 to 2016 there was a significant increasing the incidence of pneumonia in OPEN group (P=0.001) (tab.VII). The Table 8 show significant difference in pneumonia incidence between the two groups during 2005 and 2016 periods.

## DISCUSSION

From the literature data and from our experience it emerges how the lower rate of respiratory complications are correlated with the EVAR technique [15,16]. The goodness of physiotherapy in training the patients before surgery and in rehabilitating the miss evident. From our data analysis it is clear that there is a need for less hospitalization for the patients operated by EVAR. Our results, confirmed by comparative studies between the OPEN and EVAR methods, demonstrate how the endovascular method is associated with reduced postoperative complications such as mortality within 30 days, and comorbidity, compared to the OPEN surgery repair method involving laparotomy [17]. The complications correlate to the open method can commonly include cardiac, renal, hematologic, and genitourinary function [3]. The number of days in hospital is on average higher for open treatment (4.07 EVAR-11.41 Open. P-value 0.001). Infectious complications, such as pneumonia are also higher in the open method. These results are very significant considering that the EVAR group patients have a higher frequency of obesity, COPD, arterial hypertension, dyslipidemia, ischemic heart disease, coagulation disorders, steroid use, compared to patients in the open group, reaffirming superiority in short and medium term of the EVAR method, as can be seen from the tables. These benefits therefore allow us to extend the use of the EVAR method to patients with advanced age and high risk, thanks to its less invasive and more conservative nature, allowing it to become increasingly more widespread in recent years. It is noted that EVAR patients, in both periods, present a more critical clinical picture. In fact, more than 40% of patients presented with a picture of chronic obstructive pulmonary disease. The purpose of post-operative respiratory physiotherapy is to obtain an early re-expansion of collapsed alveoli and the prevention of further

complications, such as atelectasis, infections, or pneumonia. The data obtained, especially from tab. 5, give us an indication of how an effective pre-operative training protocol, an early post-operative respiratory rehabilitation improve significantly the outcome in the OPEN group.

EVAR repair techniques together with the latest and most reliable endoprosthesis, contribute to decreasing the incidence of postoperative respiratory complications, especially pneumonia. Endovascular treatment of AAA should be considered as a procedure with medium-high heart risk ranging from 3% to 7% [15]. If pre-procedural cardiac disease is identified, appropriate therapy should be considered prior to the EVAR election [16,17]. It is known that preexisting renal failure is associated with poor outcome after EVAR and that renal protection strategies should be used to avoid kidney damage, also during the follow up [18-20].

Our results concerning the postoperative length stay showed in Tables 3 and 4 are enhanced according to the Literature [14,21].

## CONCLUSIONS

Rehabilitation physiotherapy plays a fundamental role in the prevention of postoperative complications of patients undergoing OPEN treatment. Despite of the excellent results obtained in patients undergoing OPEN treatment, the lower rate of complications in EVAR group showed better results of endovascular treatment. The good outcome can be ascribed to the lower exposure of complication risk factors, such as the absence of laparotomy, the lower incidence of gold tracheal intubation (iot) and early post-operative mobilization.

**Ethical approval:** not applicable appropriate.

**Funding:** no sources of funding.

**Conflict of interest:** none.

## Contribution of paper

- Postoperative physiotherapy plays an essential role in rehabilitation after open abdominal surgery and reduces postoperative complications.
- The introduction of endovascular methods reduces the incidence of postoperative respiratory complications compared to open treatment in abdominal aortic aneurysm surgery.
- The applied postoperative treatment protocol has a favorable impact on both open and endo patients suffering from an aortic aneurysm.

## REFERENCES

1. Brewster DC, Cronenwett JL, Hallett JW Jr, Johnston KW, Krupski WC, Matsumura JS, et al. Guidelines for the treatment of abdominal aortic aneurysms. *J Vasc Surg.* 2003;37(5):1106-1117.
2. Erbel R, Aboyans V, Boileau C, Bossone E, Bartolomeo RD, Eggebrecht H, et al. 2014 ESC Guidelines on the diagnosis and treatment of aortic diseases: Document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult. The Task Force for the Diagnosis and Treatment of Aortic Diseases of the European Society of Cardiology (ESC). *Eur Heart J.* 2014;35(41):2873-2926.
3. Lederle FA, Wilson SE, Johnson GR, Reinke DB, Littooy FN, Acher CW, et al. Immediate repair compared with surveillance of small abdominal aortic aneurysms. *N Engl J Med.* 2002;346(19):1437-1444.
4. Moll FL, Powell JT, Fraedrich G, Verzini F, Haulon S, Waltham M, et al. Management of abdominal aortic aneurysms clinical practice guidelines of the European society for vascular surgery. *Eur J Vasc Endovasc Surg.* 2011;41: S1-S58.

5. Armstrong RA, Squire YG, Rogers CA, Hinchliffe RJ, Mouton R Type of Anesthesia for Endovascular Abdominal Aortic Aneurysm Repair. *J Cardiothorac Vasc Anesth.* 2019;33(2):462-471.
6. Hirsch AT, Haskal ZJ, Hertzner NR, Bakal CW, Creager MA, Halperin JL, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease): endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. *Circulation.* 2006;113(11):e463-654.
7. Kato M, Kubo A, Green FN, Takagi H, Meta-analysis of randomized controlled trials on safety and efficacy of exercise training in patients with abdominal aortic aneurysm. *J Vasc Surg.* 2019;69(3):933-943.
8. Lima RM1, Vainshelboim B, Ganatra R, Dalman R, Chan K, Myers J, Exercise Training Improves Ventilatory Efficiency in Patients With a Small Abdominal Aortic Aneurysm: A RANDOMIZED CONTROLLED STUDY. *J Cardiopulm Rehabil Prev.* 2018;38(4):239-245.
9. McConnell TR, Mandak JS, Sykes JS, Fesniak H, Dasgupta H, Exercise training for heart failure patients improves respiratory muscle endurance, exercise tolerance, breathlessness, and quality of life. *J Cardiopulm Rehabil.* 2003;23(1):10-16.
10. McCool FD. Global physiology and pathophysiology of cough: ACCP evidence-based clinical practice guidelines. *Chest.* 2006;129:48S-53S.
11. Setacci C, Sirignano P, Fineschi V, Frati P, Ricci G, Speziale F. A clinical and ethical review on late results and benefits after EVAR. *Ann Med Surg (Lond).* 2017;16:1-6.
12. Stather PW, Sidloff D, Dattani N, Choke E, Bown MJ, Sayers RD, et al. Authors' reply: Systematic review and meta-analysis of the early and late outcomes of open and endovascular repair of abdominal aortic aneurysm (*Br J Surg* 2013;100: 863-872). *Br J Surg.* 2013;100(11):1541.
13. Ma B, Wang YN, Chen KY, Zhang Y, Pan H, Yang K. Transperitoneal versus retroperitoneal approach for elective open abdominal aortic aneurysm repair. *Cochrane Database Syst Rev.* 2016;2:CD010373.
14. Zettervall SL, Soden PA, Shean KE, Deery SE, Ultee KH, Alef M, et al. Early extubation reduces respiratory complications and hospital length of stay following repair of abdominal aortic aneurysms. *J Vasc Surg.* 2017;65(1):58-64e1.
15. Greenhalgh RM, Brown LC, Kwong GP, Powell JT, Thompson SG. Comparison of endovascular aneurysm repair with open repair in patients with abdominal aortic aneurysm (EVAR trial 1), 30-day operative mortality results: randomised controlled trial. *Lancet.* 2004;364(9437):843-8.
16. Blankensteijn JD, de Jong SE, Prinszen M, van der Ham AC, Buth J, van Sterkenburg SM, et al. Two-year outcomes after conventional or endovascular repair of abdominal aortic aneurysms. *N Engl J Med.* 2005;352(23):2398-2405.
17. Siracuse JJ, Schermerhorn ML, Meltzer AJ, Eslami MH, Kalish JA, Rybin D, et al. Comparison of outcomes after endovascular and open repair of abdominal aortic aneurysms in low-risk patients. *Br J Surg.* 2016;103(8):989-994.
18. Brown LC, Brown EA, Greenhalgh RM, Powell JT, Thompson SG. Renal function and abdominal aortic aneurysm (AAA): the impact of different management strategies on long-term renal function in the UK EndoVascular Aneurysm Repair (EVAR) Trials. *Ann Surg.* 2010;251(5):966-975.
19. Gallitto E, Faggioli G, Gargiulo M, Freyrie A, Pini R, Mascoli C, et al. Planning, Execution, and Follow-up for Endovascular Aortic Aneurysm Repair Using a Highly Restrictive Iodinated Contrast Protocol in Patients with Severe Renal Disease. *Ann Vasc Surg.* 2018;47:205-211.
20. Saratzis A, Melas N, Mahmood A, Sarafidis P. Incidence of Acute Kidney Injury (AKI) after Endovascular Abdominal Aortic Aneurysm Repair (EVAR) and Impact on Outcome. *Eur J Vasc Endovasc Surg.* 2015;49(5):534-540.
21. Behrendt CA, Sedrakyan A, Rieß HC, Heidemann F, Kölbl T, Petersen J, et al. Short-term and long-term results of endovascular and open repair of abdominal aortic aneurysms in Germany. *J Vasc Surg.* 2017;66(6):1704-1711e3.