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Original Article

Rapid artificial ventricular pacing for thoracic endovascular aortic repair

Mehmet Cahit Saricaoglu, Levent Yazicioglu

Ankara University School of Medicine, Heart Center, Department of Cardiovascular Surgery, Ankara, Türkiye

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Abstract

Aim: Rapid artificial ventricular pacing (RAVP) is a reproducible method for rapid and reversible reduction of transvascular flow during endovascular procedures. This method has the potential to increase patient tolerance, reduce operation duration, infection risk, X-ray dose and facilitate early patient mobilisation. The aim of this study to compare the efficacy, safety and impact of RAVP and pharmacological-induced hypotension in patients who underwent thoracic endovascular aortic repair (TEVAR) procedures for aortic dissection and aneurysm.
Material and Methods: This retrospective, observational, case-control study was conducted between January 2014 and December 2022. The adult patients who underwent TEVAR procedures for aortic dissection and aneurysm were enrolled in this study. Mean arterial pressure, heart rate, total operation duration, incidence of endoleak, duration of intensive care unit-hospitalization stay, and hospital mortality ratio were compared between nitroglycerin induced hypotension group and RAVP group.
Results: A total of 279 patients who underwent TEVAR procedures were included in this study. The mean age of patients in this cohort was 65.6±5.7 years and 158 (56.6%) of the patients were male. Of these 279 patients, hypotension during stent-graft was achieved with nitroglycerin in 155 patients. There were no statistical differences between these two groups in terms of age, gender, body mass index, comorbidities and drugs. The blood pressure lowering effect and the heart rate during the intervention was significantly higher in RAVP. Endoleak and hospital mortality rates were similar in each group.
Conclusion: RAVP is a feasible and safe method because it paves the way for agile maneuvers to maintain optimal hemodynamic conditions. Besides this, more meticulous, accurate deployment of endograft can be established with RAVP.

Keywords: Rapid ventricular pacing, nitroglycerin, hypotension, thoracic endovascular aortic repair

INTRODUCTION

Aortic pathologies including aortic dissection, aneurysm and trauma are the most critical conditions of cardiovascular system with their rapid onset and high mortality [1]. The traditional aortic artificial vascular graft under thoracotomy with left heart or cardiopulmonary bypass for dissection or aneurysm of descending thoracic aorta treatment is more invasive and prone to more complications [1,2]. Nowadays thoracic endovascular aortic repair (TEVAR) has gradually replaced the aortic replacement as the standard operation method [1]. While launching this self-expandable stent-graft, shortly reducing cardiac contractility and stroke volume to maintain abrupt hypotension (systolic blood pressure <60 mmHg) and decrement in sheer stress is essential [3]. Therefore, appropriate settling of stent-graft on landing zone and preventing migration of graft is established. This potentially catastrophic complication can be overcome by performing rapid artificial ventricular pacing (RAVP).

Preventing hemodynamic impelling force and optimizing the

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Corresponding Author: Mehmet Cahit Saricaoglu, Ankara University School of Medicine, Heart Center, Department of Cardiovascular Surgery, Ankara, Türkiye
Email: cahitsarica@gmail.com

implantation of the stent graft is possible with several techniques. The most common used technique is pharmacological hypotension provided with nicardipine, sodium nitroprusside, nitroglycerin or adenosine. However, there are some disadvantages of each drug such as unreliable time to onset of action, non-reproducibility etc. Also, mechanical methods such as the induction of ventricular fibrillation and temporary caval occlusion by balloons can be used. However, the most appropriate and adapted technique seems to be RAVP [4].

RAVP is a reproducible method for rapid and reversible reduction of transvascular flow during endovascular procedures [5]. It produces controlled and transient systemic hypotension that can be started and ceased quickly [6]. RAVP is a simple, predictable, safe and effective method of inducing sustained hypotension, enabling precise deployment of endovascular stent grafts and safe post-stent ballooning [7]. This method has the potential to increase patient tolerance, reduce operation duration, infection risk, X-ray dose and facilitate early patient mobilisation [5]. Uncommon adverse events can also be seen; for example, a meta-analysis showed that a 2% complication rate of lung or myocardial puncture during the procedure and these complications were increased with increasing patient age [8]. The aim of this study to compare the efficacy, safety and impact of RAVP and pharmacological-induced hypotension in patients who underwent TEVAR procedures for aortic pathology including aortic dissection and aneurysm.

MATERIAL AND METHODS

This retrospective and observational study was conducted in cardiovascular surgery clinics of Ankara University between January 2014 and December 2022. The adult patients who underwent TEVAR procedures for aortic dissection and aneurysm were enrolled in this study. Patients meeting the following criteria were excluded: being <18 year-old, history of allergy to iodinated contrast or stent-graft material, free rupture of the aneurysm, intractable coagulopathy, unavailable medical reports.

Demographic characteristics of the patients were obtained from the patients' medical records. The following data were obtained for all patients; age, gender, body mass index, comorbidities (hypertension, diabetes mellitus, dyslipidemia, coronary artery disease, chronic obstructive pulmonary disease and chronic renal failure), drugs (β-receptor blocker, angiotensin converting enzyme inhibitors/angiotensin receptor blocker-(ACEi/ARB), calcium channel blocker, α-receptor blocker, vasodilator and diuretics).

The patients were divided into two groups according to hypotension inducing mechanisms; nitroglycerin induced hypotension (NG) group and RAVP group. The outcomes including mean arterial pressure (preoperative, during the intervention and after the intervention), heart rate (preoperative, during the intervention and after the intervention), total operation duration, incidence of endoleak, duration of intensive care unit (ICU)-hospitalization stay, hospital mortality ratio, accuracy of graft localization were compared between these two groups.

This research was conducted in accordance with the Declaration of Helsinki, and this study was also approved by the Ethical Committee of Ankara University Faculty of Medicine (No:2023/493). Informed consent authorizing the use of their anonymously collected data for our retrospective observational study was obtained from patients.

Operative Technique

The procedures were performed in the hybrid operating room for urgent open surgical interventions just in case there might have been complications. Following the insertion of cerebrospinal fluid drainage and pressure monitoring catheter, under general anesthesia and full monitorization, one venous and one arterial 6 French (Fr) sheath were introduced via femoral vein and femoral or brachial artery. One femoral artery was prepared for stent-graft access site with groin incision according to computerized tomography angiographic (CTA) evaluation of arterial vasculature. Intravenous heparin was administered to gain an activated clotting time of 250-300 seconds. Firstly, 5F temporary pacing bipolar electrode catheter (EndoStim®, Osypka Medical GmbH, 12489, Berlin, Germany) was passed through the sheath and located on the myocardium of right ventricle apex, then connected to a temporary external pacemaker (PACE® Model 101, Osypka Medical GmbH, 12489, Berlin, Germany). The lowest pacing threshold level was tested and catheter was fixed to the sheath. Trial run was continued till the targeted hemodynamics were achieved, before endograft deployment. Endovascular aortic repair was established with Life-Tech Ankura™ thoracic endograft (Lifetech Scientific, Shenzhen, China) or Valiant™ Captivia stent graft (Medtronic, Inc., Minneapolis, MN 55432, USA). The systolic blood pressure was dropped below 60 mmHg by rapid artificial ventricular pacing adjusted to 180-200 beats/minute or intravenous infusion of nitroglycerin and along with closely monitoring the Near Infrared Spectroscopy (NIRS) measurements, then tip capture of delivery system was meticulously released. After making sure it was safely and precisely settled on landing zone, rapid pacing was deactivated. Precision of stent-graft deployment was measured by the distance between current location of the proximal markers of the stent-graft and preconcerted anchoring point. Complementary angiography was performed to check the position of stent-graft and detect the endoleak. Then delivery system was removed and arterial access site was repaired with

restoring the blood flow.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) 23 evaluation version. The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov-Simirnov/Shapiro-Wilk's test) to determine whether or not they were normally distributed. Descriptive analysis was presented using means and standard deviations for normally distributed variables, median (min-max) for non-normally distributed variables, frequencies for ordinal variables. The significance of the difference between the groups in terms of mean and median were investigated respectively with Student's t-test and Mann Whitney U test. The Chi-square test or Fisher's exact test, where appropriate, was used to compare categorical variables in different groups. A p-value of less than 0.05 was considered to show a statistically significant result.

RESULTS

A total of 279 patients who underwent TEVAR procedures between January 2014 and December 2022 were included in this study. Mean age of patients in this cohort was 65.6±5.7 years, 158 (56.6%) patients were male. Hypertension 243 (87.1%), dyslipidemia 97 (34.8%) and coronary artery disease 72 (25.8%) were the most common comorbidities. β-receptor blocker 254 (91%), vasodilator 233 (83.5%), and ACEi/ARB 203 (72.8%) were the top 3 drugs patients used.

Of these 279 patients who underwent TEVAR, hypotension during stent-graft implantation was achieved with nitroglycerin in 155 patients. RAVP was used in 124 patients. There were no statistical differences between these two groups in terms of age, gender, body mass index, comorbidities and drugs. Comparisons of baseline demographic characteristics between NG group and RAVP group are presented in Table 1.

The blood pressure dropping effect was higher in RAVP group than NG group (76.6 mmHg vs 53.1 mmHg, p=0.03). Also in RAVP group the restoration time of blood pressure was shorter (398.1 sec vs 9.3 sec, p<0.0001) and the stent graft deployment was more accurate (4±2 mm vs 2±1 mm, p=0.48). In RAVP group, total operation duration and duration of intensive care unit stay were shorter (p<0.0001, p=0.02, respectively). Endoleak and hospital mortality rates were similar in each group (p=0.96, p=0.88, respectively) (Table 2).

Table 1. Baseline demographic characteristics of patients underwent thoracic endovascular aortic repair procedures

	All population (n=279)	NG group (n=155)	RAVP group (n=124)	P value
Age (years)	65.6±5.7	67.2±7.7	66.5±7.4	0.43
Male gender	158 (56.6)	87 (56.1)	76 (61.3)	0.46
BMI (kg/m²)	25.8±2.3	26.3±2.4	27.3±2.6	0.29
Hypertension	243 (87.1)	132 (85.2)	108 (87.1)	0.73
Diabetes mellitus	44 (15.8)	23 (14.8)	21 (16.9)	0.82
Dyslipidemia	97 (34.8)	51 (32.9)	42 (33.9)	0.67
Coronary artery disease	72 (25.8)	48 (31)	34 (27.4)	0.76
COPD	49 (17.6)	30 (19.4)	24 (19.4)	0.91
CRF	5 (1.8)	4 (2.6)	2 (1.6)	0.94
Drugs				
β-reseptor blocker	254 (91)	138 (89)	109 (87.9)	1.00
ACEi/ARB	203 (72.8)	122 (78.8)	88 (71)	0.73
Calcium channel blocker	158 (56.6)	88 (56.8)	65 (52.4)	0.59
α-reseptor blocker	20 (7.2)	11 (7.1)	8 (6.5)	0.82
Vasodilator	233 (83.5)	136 (87.7)	104 (83.9)	0.98
Diuretics	55 (19.7)	36 (23.2)	24 (19.4)	0.96

NG: nitroglycerin induced hypotension group , RAVP: rapid artificial ventricular pacing induced hypotension group, COPD: chronic obstructive pulmonary disease, CRF: chronic renal failure, ACEi/ARB: angiotensin converting enzyme inhibitors/angiotensin receptır blocker, BMI: body mass index

DISCUSSION

Table 2. Comparision of thoracic endovascular aortic repair procedures outcomes

	NG group (n=155)	RAVP group (n=124)	p value
Mean arterial pressure			
Preoperative BP (mmHg)	97.3±7.8	94.8±8.7	0.34
BP during the intervention (mmHg)	76.6±6.3	53.1±4.6	0.03
BP after the intervention (mmHg)	93.4±9.7	94.3±6.7	0.10
Restoration time of BP (seconds)	398.1±62.3	9.3±2.6	<0.0001
Total operation duration (minutes)	117.5±9.8	84.3±5.2	<0.0001
Endoleak (n)	9 (5.8)	7 (5.6)	0.96
ICU stay (days)	2.3±1.1	2.2±0.8	0.02
Duration of hospitalization (days)	7.5±2.4	7.2±1.8	0.06
Hospital mortality (n)	3 (1.94)	2 (1.61)	0.88
Accuracy of graft localization (mm)	4±2	2±1	0.48

NG: nitroglycerin induced hypotension group, RAVP: rapid artificial ventricular pacing induced hypotension group, BP: blood pressure, ICU: intensive care unit

Endovascular repair is feasible for many aortic pathologies. There is already a paradigm shift to TEVAR from traditional open aortic replacement with the advances in stent-graft technology and procedural techniques [9,10]. However, this brings with it a fundamental problem such dislodgement of stent-graft, because of impelling force of aortic blood flow and shear stress on arterial wall and stent-graft. Although there are many maneuvers in order to maintain the device stability (such as using more stiff guidewire or rapid manipulation of delivery system), optimization of blood pressure is essential for accurate positioning of endograft.

There are some methods to achieve controlled hypotension which include: 1) pharmacological agents like sodium nitroprusside, nitroglycerin, calcium channel or beta blockers and particularly adenosine for transient cardiac asystole; 2) a modified Valsalva maneuver and 3) partial occlusion of right atrium [11,12]. RAVP produces more prominent hypotension with faster and shorter duration when compared with nitroglycerin [13]. Duration of asystole can be unpredictable and individual dose adjustment can be required when adenosine is used for this purpose [14,15]. On the other hand, effectiveness of the Munich Valsalva Implantation Technique, a recently studied method, affected patients' intravascular volume status, pulmonary microcirculation and vasopressor support due to preload dependent nature of the maneuver [16]. Partial right atrial inflow occlusion can have troublesome outcomes related with vena cava filter or such as deep venous thrombosis. Its reliability and safety needs further larger studies [17]. The prominent advantage of RAVP is that onset and cessation of rapid pacing can be controlled more easily [13].

Accurate deployment of stent-graft depends on perfect imaging and hemodynamic stability. The windsock effect is the most important factor that influence this process. Therefore, dropping blood pressure during intervention is a potent method to clear the adverse impacts of the windsock effect [9]. Chen J et al. and Nienaber CA et al. showed that blood pressure was significantly lower in rapid pacing group [1,10]. Ertugay S et al. used RAVP especially in cases that zone 2 had been a landing zone to prevent graft migration due to its more effective and adjustable blood pressure lowering effect [18]. Similarly, we showed that the blood pressure dropping effect was higher in RAVP group than NG group.

The randomised controlled study by Huang WH compared stent graft positioning between sodium nitroprusside and RAVP induced hypotension during TEVAR. Researchers demonstrated that RAVP shortens the operation duration ((94±16) min vs (103±24) min), enables more precise positioning and deployment of stent-graft ($p<0.01$) [19]. We also revealed that operation duration in RAVP procedure was 33.2 minutes shorter than NG group in this study.

Serious complications related with temporary ventricular pacing are very rare [20]. Ventricular tachyarrhythmia can be seen with less than 1% incidence. In addition, there is a risk of right ventricular or atrial perforation which might seldom require open surgical repair. [10]. We experienced only two cases of self-limiting hemopericardium due to right ventricular perforation that it did not cause cardiac tamponade. Occurrence of pericardiocentesis of transient pacemaker-dependency after rapid pacing is also possible in patients with left bundle branch block [21]. We did not see this complication in our experience.

There were several limitations in this study. First; this study was a single-center, retrospective design. Secondly, the number of cases in this study were small for generalizing the results. Thirdly, we could not evaluate the impact of lower aortic pressure on cognitive and renal function.

CONCLUSION

RAVP is a feasible and safe method because it paves the way for agile maneuvers to maintain optimal hemodynamic conditions. Besides this, more meticulous, accurate deployment of endograft can be established with RACP.

Ethics Committee Approval: This research was in accordance with the Declaration of Helsinki, and this study was also approved by the Ethical Committee of Ankara University Faculty of Medicine (No:2023/493).

Patient Consent for Publication: Informed consent authorizing the use of their anonymously collected data for our retrospective observational study was obtained from patients.

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