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Hemodynamic Monitoring Using A Pulse Counter Vigileo Flotrac Cardiac Output System In Transapical Off-Pump Minimally Invasive Mitral Valve Repair

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ABSTRACT

The aim of this study was to present our anesthetic management and early hemodynamic recovery after transapical off-pump neochords implantation.
Observational prospective study. The perioperative records of 13 patients who underwent mitral valve repair using the Neochord DS1000 system were analyzed. Hemodynamic measurements recorded with the Vigileo Flotrac invasive arterial cardiac output system were evaluated.
Thirteen patients were included in the study. Transfusions of a total of 2 U of erythrocytes and 11 U of plasma were performed. After Neochord implantation, the mean cardiac output increased at a statistically significant level according to the values measured after induction p = 0.003.
Increased cardiac output measurement after placement of the neochordaes and elimination of insufficiency have emerged as indications of early hemodynamic recovery

Key Words: Mitral valve prolapse, chorda tendinea, cardiac output

Introduction

In recent years, minimally invasive cardiac surgery has become widespread because of the advantages of a small incision, rapid healing, reduced postoperative pain, improved cosmetic appearance and lower mortality, morbidity (1). Transapical minimally invasive neochord implantation is a surgical technique performed without use of cardiopulmonary bypass (CPB), through the left thoracotomy in advanced mitral regurgitation due to mitral valve (MV) prolapse or chordal rupture (2).

Transapical off-pump chordae implantation has many special concerns for anesthetists, such as hemodynamic stability, avoidance of increased blood pressure to reduce blood loss, preparation for blood salvage and initiation of bypass (3). After offpump neochord implantation, procedural success, safety, low perioperative morbidity have been reported but acute phase hemodynamic improvement has not been described yet (3-5).

The purpose of this study was to present our anesthetic management and early hemodynamic recovery after artificial neochords implantation as shown by invasive arterial cardiac output measurement (Vigileo Flotrac system) in 13 cases who underwent MV repairment.

Materials and Methods

In this study, the perioperative records of 20 patients who underwent MV repair with the Neochord DS1000 system at Sakarya University Educational Research Hospital between September 2016 and June 2017 were reviewed with approval from the Ethical Committee (71522473/050.01.04/181) of the Sakarya University Medical Faculty and it was registered on www.ClinicalTrials.gov (NCT03506217).

Preoperative demographic data (age, sex, and additional diseases), ejection fraction (EF), preoperative and postoperative transesophageal echocardiography (TEE) evaluation reports, operation and anesthesia duration, anesthetic agents, amount of blood product and fluid and hemodynamic measurements were analyzed After the patients were taken to the operating room,

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Fig. 1. Middle esophageal left ventricular long-axis image showing posterior mitral leaflet prolapses (arrow)

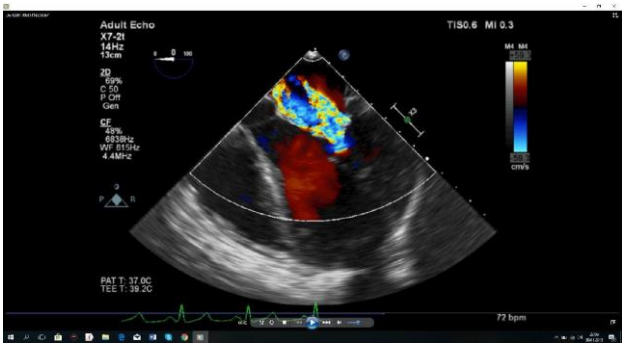

Fig. 2. Middle esophageal four-chamber image showing advanced mitral insufficiency (colored Doppler imaging)

premedication with midazolam (0.03 mg/kg) was performed and standard monitoring was provided with electrocardiography, pulse oximeter, invasive arterial pressure measurement and capnography. Two large peripheral venous routes were opened and blood samples were taken for basal arterial blood gas and activated coagulation time (ACT) measurements. External defibrillator pads were placed. A Vigileo Flotrac pulse counter invasive arterial cardiac output (CO) monitoring device was used for CO measurement. Heart rate (HR), blood pressure (BP), CO, stroke volume variance (SVV) and systemic vascular resistance (SVR) values were recorded. General anesthesia induction was achieved with 0.05–0.1 mg/kg of midazolam, 0.5–1 mg/kg of ketamine, 5–10 µg/kg of fentanyl, and 0.8–1 mg/kg of rocuronium after preoperative oxygenation in all patients. The process was continued with patient state index (Masimo, Sedline, PSI) values between 25 to 50, 5 µg/kg/h fentanyl infusion, 50% oxygen air mixture, and 6% desflurane titration. After the induction of anesthesia, internal jugular venous cannulation was performed in the presence of ultrasonography (USG). The X7-2t TEE probe (Philips Medical System) was placed through the medial path by slightly lifting the mandible. TEE recordings were continued during the assessment

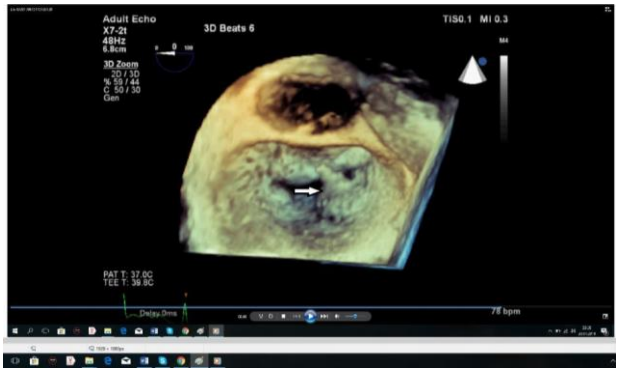

Fig. 3. Three-dimensional transesophageal echocardiography revealing a posterior leaflet prolapse (arrow marked)

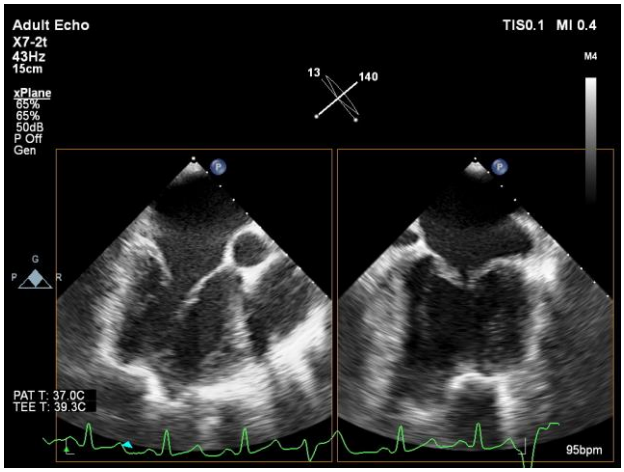

Fig. 4. Multiplan (X-plan) image of the mitral valve; the posterior-lateral ventricle intervention site was finger-pushed

of pre-interference mitral insufficiency, (Fig 1-2-3), (Video1,2,3) at the time of placement of the Neochords during the procedure, and in adjusting the chordae strains after the procedure.

Ventilation was provided with a tidal volume of 8 ml/kg and end-tidal CO_2 pressure of 30–35 mmHg. The esophageal temperature was monitored to keep the patient's body temperature above 36 °C by providing a tabletop blanket, and urine output was monitored using a Foley catheter, with an output of at least 1 ml/kg/h. The cell saver was used continuously for autotransfusion purposes throughout the operation. Esmolol in the presence of tachycardia, amiodarone infusion in the presence of arrhythmia and ephedrine, noradrenaline and dobutamine infusion in the presence of hypotension were applied. After a sufficient number of Neochord implants, according to the degree and place of the insufficiency, the insertion was terminated by adjusting the chordae lengths to the minimum **Surgical Technique:** The patient was placed in level of in sufficiency with the guidance of TEE.

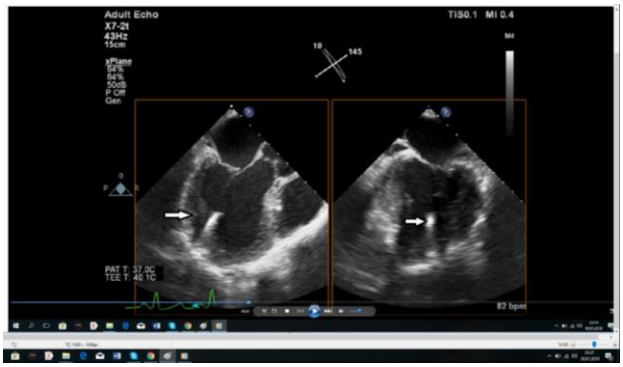

Fig. 5. Multiplan (X-plan) image of the mitral valve, showing the Neochord device moving in the left ventricle during placement of the Neochord

Fig. 6. Three-dimensional echo image of the Neochord device in the mitral valve orifice

Protamine sulfate was used for reversal of anticoagulation.

the supine position, slightly right side, keeping the left arm over the head. Left anterolateral mini-thoracotomy was carried out through the 5th intercostal with a 5–6-cm vertical incision. The left ventricular apex was determined by palpation with the guidance of two-dimensional TEE and X-plan multiple imaging (Figure 4). Two purse-string sutures were placed with plegia to control bleeding. A total of 100 IU/kg of heparin was administered before ventriculotomy, which allowed the ACT to be 250–300 s. After transapical ventriculotomy, the Neochord DS1000 (Neochord, Inc., St. Louis Park, MN, USA) system was loaded with a polytetrafluoroethylene suture and advanced through the left ventricle. X-plain mid-esophageal long-axis and mid-commussural images were used to capture the ruptured chordae segment of the prolapsed leaflet (Figures 5 and 6), (Video 5,6). After the device entered the left ventricle, the purse-string was adjusted to reduce hemorrhage and allow the device to move back and forth. Under the guidance of TEE, contact with native chordae avoided, the Neochord lengths were set, and the was reduction in insufficiency was displayed

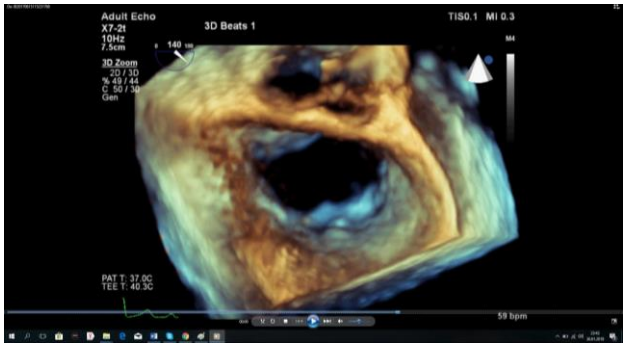

Fig. 7. The posterior leaflet mitral valve prolapse was invisible after Neochord implantation

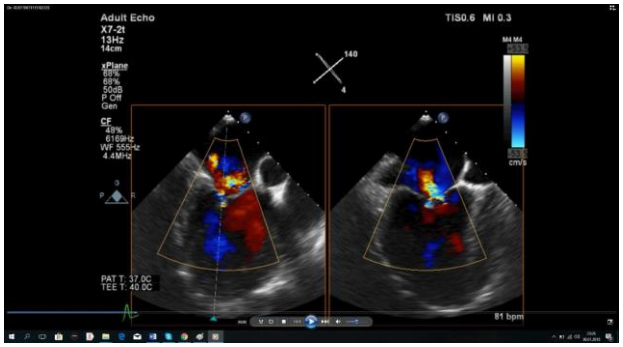

Fig. 8. First-degree residual block in the two-dimensional X-plane view after Neochord implantation

(Figures 7 and 8), (Video 7,8).

Statistical Analysis: The distributions of the data were analyzed by the single sample Kolmogorov-Smirnov test. Numerical data were expressed as the mean and standard deviation (SD), and categorical data were expressed as number and percentage. Mean values of pre-induction, post-intubation, Neochord implantation, and exit HR, MAP, SVV, CO, and SVR were analyzed by the Kruskal-Wallis test; Tukey's honest significant difference test was used for posthoc analysis. Data were analyzed with Statistical Package for the Social Sciences, version 20 (SPSS Inc., Chicago, IL, USA). The statistical significance level was accepted as $p<0.05$ in all analyses.

Results

At Sakarya University Educational Research Hospital, Neochord implantation was performed in 20 patients with advanced mitral insufficiency between September 2016 and June 2017. Thirteen patients were enrolled in the study, as the required reduction in the level of insufficiency was not achieved in one patient and open surgery was needed, and the records of the six patients were insufficient. The demographic characteristics of the patients and their additional diseases are shown in Table 1. In two patients, prolapse or

Table 1. Patient Characteristics

Age: years ± SD	50 ± 6 (43–63)
Weight: kg± SD	87.6 ± 17,4 (70–105)
Sex (n)	
female/male	2/11
Height: cm± SD	174 ± 5.8 (160–180)
EF: %± SD	59 ± 3 (55–65)
Additional diseases	
Hypertension: n (%)	1 (8.3%)
Diabetes mellitus: n (%)	1 (8.3%)
COPD: n (%)	1 (8.3%)
Peripheral vascular disease: n (%)	1 (8.3%)
Pulmonary hypertension: n (%)	3 (25%)
Previous surgery: n (%)	7 (58%)

Values are given as the mean ± SD, maximum, minimum, or number and percentage. Abbreviations: COPD, chronic obstructive pulmonary disease; EF, ejection fraction

Table 2. Intraoperative Outcomes

Intravenous fluids and transfusions	
Crystalloid: ml± SD (min–max)	1300 ± 360 (900–1700)
Colloid: ml± SD (min–max)	288.4 ± 320.2 (0–1000)
Blood: U (min–max)	0.15 (0–1)
Plasma: U (min–max)	0.84 (0–2)
Blood collected from the cell saver: ml± SD (min–max)	744 ± 300 (250–1000)
Urine: ml± SD (min–max)	343 ± 266 (50–900)
Drug infusions	
Noradrenaline: n (%)	2 (15%)
Dobutamine+noradrenaline: n (%)	1 (7.6%)
Esmolol: n (%)	4 (30%)
Amiodaron HCI: n (%)	4 (30%)
Neochord implantation	
2: n (%)	1 (7.6%)
3: n (%)	8 (61%)
4: n (%)	4 (30%)
Anesthesia duration: h ± SD	2.8 ± 0.6
Preop Hg: g/dl ± SD	13.7 ± 0.7
Postop Hg: g/dl ± SD	12.8 ± 1.4

Values are given as the mean ± SD, maximum, minimum, or number and percentage
Abbreviations: Preop Hg, Preoperative hemoglobin level; Postop Hg, Preoperative hemoglobin level

chordae was present in both the anterior and posterior segments of the MV; in eleven patients, it was present in the posterior segment only. Because of the use of cell saver, only two of the patients needed erythrocytes. In total, 2 U of erythrocytes and 11 U of plasma were given. During Neochord placement, an esmolol infusion was initiated in four patients due to tachycardia, and an amiodarone infusion was initiated in four patients with arrhythmia. Two Neochord implants were applied in one patient, three implants in seven patients, and four implants in four patients (Table 2). After Neochord implantation, ten cases of mitral insufficiency were graded as grade 1 and three cases were graded as grade 2.

The HR, MAP, SVR values did not differ during the measurement periods (Table 3).

The mean SVV increased after induction ($p=0.018$). The mean cardiac output decreased

Table 3. Changes in Vigileo Flotrac pulse counter invasive arterial cardiac output measures during different periods of Neochord implantation

	T1:Before induction	T2:After intubation	T3: Exit
HR / min	76 ± 6 (68–88)	74 ± 9 (60–85)	84 ± 13 (60–104)
MAP: mmHg	90 ± 13 (65–106)	76 ± 10 (52–87)	77 ± 9 (65–90)
SVV : %	8 ± 2 (5–10)+	11 ± 6 (4–22)	11 ± 5 (5–22)
CO: L/min	5.5 ± 1.7(3–8)+	4.18 ± 0.8(3.2–6)#	5.9 ± 1.7(4.1–9.7)
SVR:	-	1525 ± 215	1108 ± 291
dyn.sn.cm		(1335–1736)	(65–90)

Values are given as the mean ± SD [minimum–maximum]
Abbreviations: HR, heart rate; MAP, mean arterial pressure; CO, cardiac output; SVR, systemic vascular resistance; SVV, stroke volume variance.
+T1 compared to T2, $p<0.05$
#T2 compared to T3, $p<0.05$

significantly after induction compared to the pre-induction value ($p=0.036$). After Neochords implantation, the mean cardiac output increased significantly ($p=0.005$) relative to the values at post-induction.

Discussion

Mitral insufficiency is one of the most common heart valve diseases (6) and for correction partial sternotomies, limited-access thoracotomies are the preferred approach (7). Currently, MV repair with minimally invasive methods is as safe as standard sternotomy and is widely used in many centers with positive short- and long-term results (5). Transapical chordae implantation is the process of reconstruction of normal leaflet movement with real-time two- or three-dimensional TEE guidance (in neochordae implantation and tension adjustment) using a Neochord DS1000 system (Neochord, Inc., St. Louis Park, MN, USA. The results showed significant clinical benefit over a 3-month follow-up period (8). The efficacy of this technique has been demonstrated in animals (9,10) and clinical studies (11-14).

In a series of 62 patients, effective chordae implantation was possible in all patients, where 88% of these patients had posterior leaflet prolapsus (11). The best candidates for this procedure are patients without anular dilatation and a postoperative coaptation height >7 mm (15).

According to Samalavicius R.S.at all (3) although only prolapsing and flail lesions are suitable for neochord implantation, their results demonstrated significant reduction in MR combined with a low rate of postoperative complications, rare blood product transfusion and no mortality in 76 patients.

Today, the use of minimally invasive CO monitor techniques in operating rooms and intensive care units have increased. Minimally invasive monitoring technique refers to less invasive monitoring techniques than a pulmonary artery catheter. One of these, the Vigileo Flotrac system (Erwin LifeSciences, Irvine, CA, USA), requires a special transducer to connect standard radial or femoral arteries and is connected to a Vigileo monitor. For cardiac output estimation, the SD of the pulse rate relative to the normal stroke volume based on the patient's demographic data is sampled within 20 s. Sudden hemodynamic changes may occur due to blood loss as a result of the device movement toward the left ventricle, mitral valve and left atrium. Blood transfusions, inotropic support and emergency cardiopulmonary bypass preparations should be made.

Aspiration of the collected blood to the cell saver and rapid delivery through large-diameter vessels reduce hemodynamic changes and need for urgent homologous transfusions (16-18). In our cases, the hematocrit values of the patients were stable due to cell saver usage and only 2 U of red blood cell were transfused.

External defibrillator pads were placed on the chest for defibrillation if needed during the operation. A tabletop heating blanket and intravenous liquid heating lines were used to keep the patient's temperature >36°C.

Neochord implantation was not successful in one of our patients and MV replacement was performed. Real-time TEE guidance from the beginning to the end of the operation, stabilized hemodynamics, immediate replacement of blood loss, tracking the rhythm and minimally invasive anesthesia and pain techniques form the foundations of successful repair.

Kavaklı et al. (19) reported successful transapical off-pump MV repairment of 12 patients, they used dual-lumen tube and cell saver, 0.8 U of blood and 2 U of plasma were given in the intensive care unit and according to them sudden hemodynamic deterioration was a common condition during the procedure. Comparison of preoperative and discharge values showed that, left atrial diameter decreased from 46 to 43 mm, the left ventricular end-diastolic diameter decreased from 55 to 46 mm, and the left ventricular end-systolic diameter decreased from 34 to 32 mm, (19). Left ventricular and left atrial reversal remodeling was observed by Rucinskas et al. (14) at 6 months follow-up in 13 patients; the mean end-diastolic diameter decreased from 57 to 53 mm. Patzelt et al. (4) performed hemodynamic examinations using echocardiography and invasive parameters in 101 patients undergoing percutaneous MV repair and found an increase in CO and a decrease in pulmonary artery systolic pressure immediately after repair. Gaemperli et al. (20) reported that percutaneous mitral valve repair with the Mitraclip system improves hemodynamic profiles and induces reverse left ventricular remodeling by reducing left ventricular preload while preserving contractility. Similarly, in our study there was a significant increase in cardiac output after the correction of mitral regurditation.

Neokord implantation was performed in 20 patients during the study period, but only 13 patients included due to lack of records related to cardiac output. Cardiac output could olso be measured and volum status could be assessed additionaly with echo. But these datas are not available in our recordings.

In our study, increased cardiac output values after placement of the neochordaes and elimination of cardiac insufficiency have indicated early hemodynamic recovery.

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Author contributions UK, HSK carried out the Manuscript preparation. AFE carried out the review of manuscript. HSK carried out the literature search. IK, BK carried out the data collection

Compliance with ethical standards

Conflict of interest All authors have no conflict of interest to disclouse

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