The relationship between aortic calcification on chest radiograph and neurocognitive impairment after coronary artery bypass grafting

Göğüs grafisinde aort kalsifikasyonu ve koroner arter baypas greffleme sonrası nörokognitif bozulma arasındaki ilişkisi

Amaç:
Bu çalışmada, koroner arter baypas greffleme yapılan hastalarda ameliyat öncesi göğüs grafisini tespit edilen aort kalsifikasyonu ile ameliyat sonrası nörokognitif bozulma arasındaki ilişki araştırıldı.

Bulgular:
Çalışma planı: Ocak 2019 - Temmuz 2019 tarihleri arasında kliniğiimizde koroner arter baypas greffleme yapılan toplam 124 hasta (101 erkek, 23 kadın; ort. yaş: 59.9±8.8 yıldır; dağılım, 34-84 yıldır) çalışmaya alındı. Bu hastaların ameliyat öncesi çekilen göğüs grafiyesinde aort tozulu üzerinde aort kalsifikasyonu olan 35'i hasta grubunu oluşturmaktadır. Aort kalsifikasyonu olmayan 89 hasta ise kontrol grubunu oluştururdu. Aort kalsifikasyonu saptanan hastalara bu bulguyu bilgisayarlı tomografi anjiyografi uygulandı ve çıkan aort ve arkus aorta kalsiyum skorları hesaplandı. Nörokognitif disfonksiyon, Standartize Mini-Mental Test ile değerlendirildi. Ameliyat sonrası delirium, yoğun bakım ünitesinde konfüzyon değerlendirme testi ile değerlendirildi. Gruplar demografik, ameliyat ve ameliyat sonrası verileri göre karlaştırıldılardır.

Özet:
Bu çalışmada, koroner arter baypas greffleme yapılan hastalarda ameliyat öncesi göğüs grafisini tespit edilen aort kalsifikasyonu ile ameliyat sonrası nörokognitif bozulma arasındaki ilişki araştırıldı. Bu çalışmada, koroner arter baypas greffleme yapılan hastalarda ameliyat öncesi göğüs grafisini tespit edilen aort kalsifikasyonu ile ameliyat sonrası nörokognitif bozulma arasındaki ilişki araştırıldı.
Coronary artery bypass grafting (CABG) can be performed with acceptable mortality and morbidity rates in the current era. Despite advances in preoperative imaging and increased surgical experience, the operative technique inherently brings along inevitable complications. Neurological and neurocognitive impairments are among the most serious of these complications.[1-3]

Postoperative neurocognitive dysfunction (POND), characterized by impaired attention, concentration, and memory with possible long-term effects, frequently occurs following CABG.[4] Three main mechanisms are held responsible for POND: microembolism, insufficient cerebral perfusion, and systemic inflammatory response.[1,5] The CABG patients are often accompanied by advanced age, carotid artery stenosis, and diabetes mellitus (DM), which may all increase the risk of POND. The incidence of POND in the early postoperative period after CABG varies between 20 and 50%.[4]

Aortic calcification (AC) is an advanced complication of atherosclerosis that stems from atheroma plaques. In patients with AC, aortic manipulation, aortic cross-clamping, and mobilization of atheromatous debris in the ascending aorta by jet flow at the beginning of cardiopulmonary bypass (CPB) cause microembolizations.[5] Severe AC can be seen in 2% of cardiac surgery patients and this rate can be as high as 30% with the increased age.[6]

Detection of AC is possible on posteroanterior chest radiography (CR), which is a routine preoperative study of CABG patients.[7] Computed tomography (CT) of patients with AC can reveal the localization, structure, and calcium density of AC and, thus, may help to predict the risk of POND and to reduce the risk by optimal surgical planning. In the present study, we aimed to investigate the association between AC detected on preoperative CR and POND in patients undergoing elective CABG.

PATIENTS AND METHODS

This single-center, prospective, case-control study was conducted at Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital, Department of Cardiovascular Surgery between January 2019 and July 2019. The patients over 18 years of age who underwent isolated on-pump CABG were included in the study. Of 750 patients who underwent open heart surgery throughout the study period, 124 (101 males, 23 females; mean age: 59.9±8.8 years; range, 34 to 84 years) who met the inclusion criteria were screened. Among 124 patients, 35 whose CR revealed AC in the aortic knuckle were included as the patient group. The control group consisted of 89 patients without AC. Patients who had neuropsychiatric diseases such as psychosis, dementia, and mental retardation that could affect psychometric analysis and neurocognitive functions, previous cerebrovascular accident (CVA), illiteracy, visual and hearing impairment, underwent emergent CABG, had moderate and severe valvular disease, intracardiac thrombus, preoperative atrial fibrillation (AF) and flutter, underwent off-pump CABG, and previous open heart surgery were excluded from the study. A written informed consent was obtained from each patient. The study protocol was approved by the Haydarpaşa Numune Training and Research Hospital Clinical Research Ethics Committee (HNEAK-KAEK-2018/9). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Definitions

Hypertension was defined as a systolic or diastolic pressure of ≥140 or ≥90 mmHg, respectively. Diabetes mellitus was defined as a fasting glucose level greater than 126 mg/dL or the use of insulin, antidiabetic agents. Hyperlipidemia was defined as a serum total cholesterol of ≥240 mg/dL, serum triglyceride of ≥200 mg/dL, or low-density lipoprotein cholesterol of ≥130 mg/dL.

Glomerular filtration rate (GFR) was calculated using the Chronic Kidney Disease Epidemiology
Table 1. Baseline characteristics of study population

|                                         | Control group (n=89) | Patient group (n=35) | p   |
|----------------------------------------|----------------------|----------------------|-----|
| **Baseline characteristics**           | n %                  | Mean±SD     | Median | Min-Max | n %                  | Mean±SD     | Median | Min-Max |       |
| Age (year)                             | 57.8±8.5             |              | 65.4±6.8 | <0.001  |                      |              |        |         |        |
| Sex                                    |                      |              |        |         |                      |              |        |         |        |
| Male                                   | 75 84.3              |              | 26 74.3 | 0.198   |                      |              |        |         |        |
| Low ejection fraction (<50%)           | 16 18.0              |              | 10 28.6 | 0.192   |                      |              |        |         |        |
| Diabetes mellitus                      | 44 49.4              |              | 21 60.0 | 0.289   |                      |              |        |         |        |
| Hypertension                           | 54 60.7              |              | 24 68.6 | 0.413   |                      |              |        |         |        |
| Hyperlipidemia                         | 40 44.9              |              | 14 40   | 0.617   |                      |              |        |         |        |
| Chronic kidney disease                 | 3 3.4                |              | 4 11.4  | 0.098   |                      |              |        |         |        |
| Chronic lung disease                   | 3 3.4                |              | 4 11.4  | 0.098   |                      |              |        |         |        |
| Carotid artery stenosis                | 7 7.9                |              | 9 25.7  | 0.011   |                      |              |        |         |        |
| Vertebrobasilar insufficiency          | 23 25.8              |              | 10 28.6 | 0.757   |                      |              |        |         |        |
| Family history of CVA                  | 12 13.5              |              | 2 5.7   | 0.182   |                      |              |        |         |        |
| Smoking habit (pack-year)              | 25 0-40              |              | 20 0-40 | 0.912   |                      |              |        |         |        |
| Preoperative GFR                       | 86.5 77.4-97.5       |              | 84.6 67.8-93 | 0.864 | |

Operative and postoperative characteristics

|                                         | n %                  | Mean±SD     | Median | Min-Max | n %                  | Mean±SD     | Median | Min-Max | p   |
|----------------------------------------|----------------------|-------------|--------|---------|----------------------|-------------|--------|---------|-----|
| CPB time                               | 108.1±34.4           |             | 104.3±30 |<0.001  |                      |             |        |         |     |
| Aortic cross-clamp time                | 68.2±26.4            |             | 64.3±23.6 |0.444   |                      |             |        |         |     |
| Side clamping for proximal anastomoses | 64 71.9              |             | 27 77.1 | 0.553   |                      |             |        |         |     |
| ES replacement                         | 39 43.8              |             | 20 57.1 | 0.181   |                      |             |        |         |     |
| GFR (24th postoperative hour)          | 92.9 77-104.2        |             | 84.7 65-95 |0.010   |                      |             |        |         |     |
| GFR (120th postoperative hour)         | 98.5 91.4-105.5      |             | 92 80.9-98 |0.002   |                      |             |        |         |     |
| Early delirium                         | 4 4.5                |             | 3 8.6  | 0.310   |                      |             |        |         |     |
| Late delirium                          | 8 9.0                |             | 4 11.4 | 0.454   |                      |             |        |         |     |
| Cerebrovascular accident                | 1 1.1                |             | 0 0.0  | 0.718   |                      |             |        |         |     |
| Transient ischemic attack              | 1 1.1                |             | 2 5.7  | 0.192   |                      |             |        |         |     |
| Epileptic seizure                      | 0 0.0                |             | 1 2.9  | 0.282   |                      |             |        |         |     |
| Postoperative AF                       | 20 22.5              |             | 8 22.9 | 0.963   |                      |             |        |         |     |
| ICU stay (day)                         | 1.0±0.3              |             | 1.3±0.9 | 0.187   |                      |             |        |         |     |
| In-hospital mortality                  | 0 0.0                |             | 2 5.7  | 0.078   |                      |             |        |         |     |

SD: Standard deviation; Min: Minimum; Max: Maximum; CVA: Cerebrovascular accident; GFR: Glomerular filtration rate (mL/min/1.73m²); CPB: Cardiopulmonary bypass; ES: Erythrocyte suspension; AF: Atrial fibrillation; ICU: Intensive care unit.
Table 2. Aortic calcification scores according to the presence of carotid artery stenosis

| Carotid artery stenosis (n=26) | Carotid artery stenosis (n=9) |
|--------------------------------|--------------------------------|
|                                 | No                            | Yes                           | p     |
|                                 | Median | Min-Max | Median | Min-Max | 0.909  |
| Ascending aorta CS              | 137    | 20-311  | 103    | 0-655   | 0.042  |
| Aortic arch CS                  | 912    | 258-1557| 1611   | 915-2957| 0.089  |
| Total aortic CS                 | 1179   | 498-2015| 2246   | 1057-3904| 0.089  |

CS: Calcium score.

Collaboration (CKD-EPI) equation. Carotid artery stenosis and vertebrobasilar insufficiency were assessed with preoperative Duplex ultrasound. A significant carotid artery lesion was defined as ≥50% stenosis. Bilateral vertebral artery flow less than 200 mL/min was accepted as vertebrobasilar insufficiency. The most recent values before surgery were taken into account for laboratory values.

**Assessment of AC**

All CRs were evaluated by at least two specialists from the radiology and cardiovascular surgery departments. As defined by Hashimoto et al.,[7] patients with AC in the aortic knuckle seen on CR were included in the patient group and those without AC were included in the control group (Figure 1).

All patients in the patient group underwent non-contrast thoracic CT angiography (Toshiba, Aquillion 64 CT) with 3-mm slices. The calcific lesion was defined as an increase of ≥130 Hounsfield units (HU) in three consecutive pixels. Aortic calcification on CT scan was defined as any calcific lesion in the ascending and/or aortic arch. Ascending aorta calcium score (CS) and aortic arch CS were calculated using the method described by Agatston et al.,[8] using semi-automatic Vitrea® 2.0 (Vital Images, Minnetonka, MN) imaging software. The total aortic CS was calculated as the sum of ascending aorta and aortic arch CSs. High ascending aorta and aortic arch CSs were defined as CS ≥2,250 Agatston units (AU).[9]

**Surgical procedure**

General anesthesia was induced with propofol, fentanyl, and rocuronium bromide. The CPB was achieved by cannulation of the ascending aorta and two-stage right atrial venous cannulation. Aortic cross-clamp was applied. Cardiac arrest was achieved by antegrade hypothermic blood cardioplegia and the patients were cooled down to a body core temperature of 32°C. After completion of distal anastomoses, the aortic clamp technique for proximal anastomoses (cross or lateral) was decided by the surgeon according to the extent of AC.

**Assessment of neurological impairment**

Neurological examination was done in the pre- and postoperative periods. Neurological deficits such as paresis, plegia, aphasia, epileptic attack, and transient ischemic attack were recorded, and ischemic areas were evaluated by cranial CT and/or magnetic resonance imaging (MRI).

Postoperative delirium was evaluated at 24 h using the Confusion Assessment Method in Intensive Care Unit (CAM-ICU) test and defined as early-stage delirium.[10,11] Delirium emerging with ≥24 h of ICU stay or recurrent ICU admission were evaluated daily by the CAM-ICU test and defined as late-stage delirium.

We used the Standardized Mini-Mental State Examination (SMMSE) to assess postoperative neurocognitive impairment. The primary endpoints of the study were the SMMSE score decline and percentage decline. Secondary endpoints were the presence of delirium, and major cerebrovascular events. The SMMSE consists of several sections that evaluate orientation, recording memory, attention and calculation, recall, and language skills. Patients answer questions scored between 0 and 30.[12,13] The SMMSE was conducted on the day before surgery and on postoperative Days 5-7 under appropriate communication conditions. The preoperative test result was accepted as the baseline value of the patient. Both pre- and postoperative SMMSE scores were compared, and score decline and percentage decline at the SMMSE scores were calculated. It was assumed that the patients with an increase in the postoperative SMMSE scores compared to the preoperative scores were not affected by surgery in terms of neurocognition, and positive
SMMSE score changes were defaulted to zero. Both groups were compared for changes in the SMMSE scores and other perioperative factors which affect neurocognitive function.

**Statistical analysis**

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). To test for normality, the Shapiro-Wilks test was used. Nominal variables were expressed in number and percentage, while normally distributed continuous variables were expressed in mean ± standard deviation (SD) and non-normally distributed continuous variables in median (interquartile range [IQR]). The chi-square test was used for nominal values in comparison of the groups, the Fisher exact chi-square test in case of expected frequencies below 5, the independent samples t-test for comparison of parametric data, and the Mann-Whitney U test for comparison of non-parametric data. Multiple groups without normal distribution were compared using the Kruskal-Wallis test with Bonferroni correction. A $p$ value of <0.05 was considered statistically significant.

**RESULTS**

Both groups were compared in terms of demographic and operative variables (Table 1). The patient group was significantly older (65.4±6.8 years vs. 57.5±8.5 years, respectively; $p<0.001$) and had a higher number of cases with carotid artery stenosis (25.7% vs. 7.9%, respectively; $p=0.011$). Postoperative 24-h and 120-h GFRs were lower in the patient group ($p=0.010$, $p=0.002$, respectively).

Of all 124 patients, there were four (3.2%) ischemic events: one patient had an ischemic stroke and three patients had transient ischemic attacks. There was no significant difference between the groups in terms of major neurological complications.

Patients with and without carotid artery stenosis were compared for their ascending aorta, aortic arch, and total aortic CSs (Table 2). The aortic arch CS was higher in the patients with carotid artery stenosis ($p=0.042$), while the ascending aorta and total aortic CS were not significantly different ($p=0.909$, $p=0.089$, respectively).

Although the number of the patients with decreased SMMSE scores in the patient group (48.6%) was higher than the control group (34.8%), this result was not statistically significant. The SMMSE score decline and percentage decline were compared between the groups, yielding no significant difference (Table 3).
Changes in the SMMSE scores were further compared between the control group, patients with low aortic arch CS, and high aortic arch CS. The patients with high aortic arch CSs showed a decline in their postoperative SMMSE scores ($p=0.026$) (Table 4). Post-hoc analysis with Bonferroni correction revealed the difference between high aortic arch CS and control groups to be significant for both absolute decline and percentage decline in the SMMSE scores (Figure 2). However, there was no significant decline in the SMMSE scores according to the ascending aorta CS and total aortic CSs.

**DISCUSSION**

Aortic calcification detectable on CR has been shown to be associated with DM, renal disease, and adverse cardiovascular events, although the association of AC detectable on CR for POND in CABG patients has not been studied, yet.$^{[7,14]}$ In the present study, we investigated the association between AC detected on preoperative CR and POND in patients undergoing elective CABG. Our study results showed a decline in the postoperative neurological function as assessed by SMMSE with an increased calcification on aortic arch that was detectable on CR.

Computed tomography is an easy and effective diagnostic tool to define the extension of the AC detected on CR. Determination of the ascending aorta and aortic arch CS values is possible with non-contrast CT angiography. High aortic CS has been found to be associated with DM, and adverse cardiovascular events postoperatively.$^{[15,16]}$ The most difficult decision for us was determining the cut-off value for the high aortic CS distinction. Although there was a previously described cut-off value for aortic valve CS (high/low) in previous guidelines, there was no defined cut-off value for ascending aorta and aortic arch CS in the literature.$^{[17]}$ We defined the value of $\geq 2,250$ AU for aortic CS in our study, which was found to be associated with poor clinical outcomes in aortic valve replacement patients.$^{[9]}$ In this study, the aortic arch CS was found to be related to carotid artery stenosis in the patient group. This can be explained by the proximity of the carotid artery to the aortic arch, rather than the ascending aorta. Carotid artery stenosis was also 3.2 times higher in our patient group.
In previous studies, advanced age and carotid artery intima-media thickness was also found to be related to AC on CR.[7,14] Therefore, it seems to be reasonable to screen patients with AC for carotid stenosis, if not routinely performed before CABG.

Aortic cross-clamp time, CPB time, AF, and blood transfusions are the other factors which are thought to be implicated in the etiology of POND.[18-23] Operative strategies including single aortic clamp and care against aortic manipulation may reduce the risk for POND by decreasing microembolism. No-touch technique for proximal anastomoses, off-pump surgery, and hybrid procedures can be reliable alternatives in patients with AC to prevent POND and overall mortality.[24] These strategies may be more important for patients with preoperatively detected AC to prevent POND and CVA.

Patients with AC may be also susceptible to other non-neurological morbidities after cardiac surgery. Aortic calcification in thoracic aorta is associated with left ventricular hypertrophy.[9] According to Korkmaz et al.,[25] AC detected on CR was an independent predictor of complex coronary artery lesions. In addition, AC in the descending aorta was found to be associated with acute kidney injury and in-hospital mortality.[26] In our patients with AC, postoperative GFR was lower, despite similar preoperative renal functions and comorbidities.

The relationship between delirium and POND after CABG has been demonstrated by Saczynski et al.[27] and it is known that prolonged ICU stay is associated with delirium.[27-29] In our study, daily CAM-ICU tests were conducted during the ICU stay, and no significant difference was found between the groups in terms of early or late delirium. Delirium has multifactorial causes and whether AC is a risk factor requires other dedicated studies that focus on this relationship.

One of the main limitations to the present study is that our sample size is relatively small due to the highly selective exclusion criteria. Although the rate of AC in CABG patients resembles our study population, the amount of the groups is statistically difficult to compare. In addition, the patient group was significantly older which may have led to a bias. On the other hand, advanced age, carotid artery stenosis, and AC are relevant and expected to be found to be concomitant conditions. Further randomized-controlled studies are needed to reveal the exact association of AC and neurocognitive impairment. A challenge in defining POND after CABG is the tests used for this purpose which all have their own drawbacks. In this study, we used the SMMSE for neurocognitive assessment, despite its disadvantages such as the ceiling effect, since it is a simple test that is easy to conduct and is widely used in the evaluation of delirium and dementia. Finally, since this study is an observational study, the surgeons performed their operations with their routine technique. Further well-designed studies with a standardized clamp technique and proximal anastomosis may produce more accurate results for neurocognitive impairment. Nevertheless, to the best of our knowledge, this is the first study to investigate the relationship between AC detectable on CR and neurocognitive outcomes in CABG patients and we believe it provides additional contribution to the body of knowledge on this topic.

In conclusion, neurocognitive impairment after coronary artery bypass grafting may be associated with aortic calcifications detected on chest radiography. The patients with higher aortic arch calcium scores on computed tomography may have worse neurocognitive outcomes. It would be wise to perform computed tomography in patients with aortic calcifications as evidenced by chest radiography to evaluate the extent of calcification and neurocognitive outcomes.

**Declaration of conflicting interests**

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

**Funding**

The authors received no financial support for the research and/or authorship of this article.

**REFERENCES**

1. Hammon JW, Stump DA, Butterworth JF, Moody DM, Rorie K, Deal DD, et al. Coronary artery bypass grafting with single cross-clamp results in fewer persistent neuropsychological deficits than multiple clamp or off-pump coronary artery bypass grafting. Ann Thorac Surg 2007;84:1174-8.
2. Alexander JH, Smith PK. Coronary-artery bypass grafting. N Engl J Med 2016;374:1954-64.
3. Özyalçın S, et al. Does uncontrolled diabetes mellitus affect cerebral hemodynamics in heart surgery? Turk Gogus Kalp Dama 2020;28:84-91.
4. Yuan SM, Lin H. Postoperative cognitive dysfunction after coronary artery bypass grafting. Braz J Cardiovasc Surg 2019;34:76-84.
5. Andersen ND, Hart SA, Devendra GP, Kim ESH, Johnston DR, Schroder JN, et al. Atheromatous disease of the aorta and perioperative stroke. J Thorac Cardiovasc Surg 2018;155:508-16.
6. Buz S, Pasic M, Unbehauen A, Drews T, Dreyssse S, Kuckuck M, et al. Trans-apical aortic valve implantation in patients with severe calcification of the ascending aorta. Eur J Cardiothorac Surg 2011;40:463-8.

7. Hashimoto H, Iijima K, Hashimoto M, Son BK, Ota H, Ogawa S, et al. Validity and usefulness of aortic arch calcification in chest X-ray. J Atheroscler Thromb 2009;16:256-64.

8. Agatston AS, Janowitz WR, Hildner FJ, Zusmer NR, Viamonte M Jr, Detrano R. Quantification of coronary artery calcium using ultrafast computed tomography. J Am Coll Cardiol 1990;15:827-32.

9. Cho JJ, Chang HJ, Heo R, Kim IC, Sung JM, Chang BC, et al. Association of thoracic aorta calcium score with left ventricular hypertrophy and clinical outcomes in patients with severe aortic stenosis after aortic valve replacement. Ann Thorac Surg 2017;103:74-81.

10. Ely EW, Margolin R, Francis J, May L, Truman B, Dittus R, et al. Evaluation of delirium in critically ill patients: Validation of the Confusion Assessment Method for the Intensive Care Unit (CAM-ICU). Crit Care Med 2001;29:1370-9.

11. Ayrap Ü, Kanbak M, Yorgancı K, Özdemir H, Akıncı SB, et al. Yoğun bakım ünitesinde konfüzyon trajectorileri (CAM-ICU). Crit Care Med 2001;29:1370-9.

12. Korkmaz L, Adar A, Ata Korkmaz A, Erkan H, Ağaç F, et al. Aortic arch calcification detectable on chest X-ray. J Atheroscler Thromb 2009;16:256-64.

13. Güngen C, Ertan T, Eker E, Yaşar R, Engin F. Standardize Mini Mental Test'in Türk toplumunda hafif demans tanılarında geçerlik ve güvenirlik çalışması. Türk Anestezi ve Reanimasyon Dergisi 2005;33:333-41.

14. Iijima K, Imazio M, et al. Trans-apical aortic valve implantation in patients with severe calcification of the ascending aorta. Eur J Cardiothorac Surg 2011;40:463-8.

15. Salis S, Mazzanti VV, Merli G, Salvi L, Tedesco CC, Veglia F, et al. Cardiopulmonary bypass duration is an independent predictor of morbidity and mortality after cardiac surgery. J Cardiothorac Vasc Anesth 2008;22:814-22.

16. Goto T, Maekawa K. Cerebral dysfunction after coronary artery bypass surgery. J Anesth 2014;28:242-8.

17. Baumgartner H, Falk V, Bax JJ, De Bonis M, Hamm C, Holm PJ, et al. 2017 ESC/EACTS Guidelines for the management of valvular heart disease. Eur Heart J 2017;38:2739-91.

18. Stanley TO, Mackensen GB, Grocott HP, White WD, Blumenthal JA, Laskowitz DT, et al. The impact of postoperative atrial fibrillation on neurocognitive outcome after coronary artery bypass graft surgery. Anesth Analg 2002;94:290-5.

19. Hogue CW, Fucetola R, HERSHEY T, Freedland K, Dávila-Román VG, Goate AM, et al. Risk factors for neurocognitive dysfunction after cardiac surgery in postmenopausal women. Ann Thorac Surg 2008;86:511-6.

20. Kapoor MC. Neurological dysfunction after cardiac surgery and cardiac intensive care admission: A narrative review part 1: The problem; nomenclature; delirium and postoperative neurocognitive disorder; and the role of cardiac surgery and anesthesia. Ann Card Anaesth 2020;23:383-90.

21. Kapoor MC. Neurological dysfunction after cardiac surgery and cardiac intensive care admission: A narrative review part 2: Cognitive dysfunction after critical illness; potential contributors in surgery and intensive care; pathogenesis; and therapies to prevent/treat perioperative neurological dysfunction. Ann Card Anaesth 2020;23:391-400.

22. Zubarevich A, Kadyraliev B, Arutyunyan V, Chragyan V, Askadinov M, Sozkov A, et al. On-pump versus off-pump coronary artery bypass surgery for multi-vessel coronary revascularization. J Thorac Dis 2020;12:5639-46.

23. Saczynski JS, Marcantonio ER, Quach L, Fong TG, Gross A, Bingold TM, et al. Descending aortic calcification and coronary artery lesion complexity in non-ST-segment elevation acute coronary syndrome patients. Turk Kardiyol Dern Ars 2012;40:606-11.

24. Nowak-Machen M, Rawn JD, Shekar PS, Mitani A, Tuli S, Bingold TM, et al. Descending aortic calcification increases renal dysfunction and in-hospital mortality in cardiac surgery patients with intraaortic balloon pump counterpulsation placed perioperatively: A case control study. Crit Care 2012;16:R17.

25. Kapoor MC. Neurological dysfunction after cardiac surgery and cardiac intensive care admission: A narrative review part 1: The problem; nomenclature; delirium and postoperative neurocognitive disorder; and the role of cardiac surgery and anesthesia. Ann Card Anaesth 2020;23:383-90.

26. Saczynski JS, Marcantonio ER, Quach L, Fong TG, Gross A, Bingold TM, et al. Descending aortic calcification and coronary artery lesion complexity in non-ST-segment elevation acute coronary syndrome patients. Turk Kardiyol Dern Ars 2012;40:606-11.

27. Salis S, Mazzanti VV, Merli G, Salvi L, Tedesco CC, Veglia F, et al. Cardiopulmonary bypass duration is an independent predictor of morbidity and mortality after cardiac surgery. J Cardiothorac Vasc Anesth 2008;22:814-22.

28. Stanley TO, Mackensen GB, Grocott HP, White WD, Blumenthal JA, Laskowitz DT, et al. The impact of postoperative atrial fibrillation on neurocognitive outcome after coronary artery bypass graft surgery. Anesth Analg 2002;94:290-5.

29. Şaşkın H, Özcan KS, Düzyol Ç, Maçika H, Aksoy R, İdiz M. An easily overlooked clinical phenomenon after coronary artery bypass graft surgery: Postoperative delirium. Turk Gogus Kalp Dama 2016;24:248-57.