Lower surgical Apgar score is predictive on delirium in patients following off-pump coronary artery bypass grafting

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Abstract

Objective To determine the predictive value of surgical Apgar score on delirium postoperatively following OPCABG. Method Intraoperative anesthesia data of patients underwent OPCABG during the period of January 2012 and December 2019 were reviewed and SAS score of each patient was calculated. Relationship between SAS score and postoperative occurrence of delirium were analyzed to determine the underlying mechanism. Results There are a total of 436 patients included with a mean age of 62.8±13.8 and 61.2±16.8 in each group. Patients in Delirium group had significantly higher incidence of heart failure (P=0.043) preoperatively in the Delirium group. No significant difference was observed referring to ASA PS III (P=0.102) and no significant difference was observed in duration of the surgery and anesthesia. Also no significant differences was observed as to dexmedetomidine and propofol use (P=0.256, P=0.278). The mean SAS score was in 4.2±0.8, 7.8±1.2 in two groups respectively (P¡0.001) and 96(22.02%) postoperative delirium events were recorded. Patients in Delirium group had much more EBL (P¡0.001) while LHR (P=102) showed no significant statistical difference between two groups. Univariate and multivariate regression analysis showed that the intraoperative SAS score was significant predictors of delirium following OPCABG (P¡0.001; P¡0.001). After adjustment for other clinical predictors, the addition of SAS also improved and the area under the curve to predict delirium was 0.934 (95%CI, 0.907-0.960, P¡0.001). Conclusions Intraoperative SAS score is associated with postoperatively following OPCABG and SAS score may be a valuable component to improve preoperative risk stratification of delirium among patient under OPCABG.

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Objective To determine the predictive value of surgical Apgar score on delirium postoperatively following OPCABG.

Method Medical records and intraoperative anesthesia data of all patients underwent OPCABG during the period of January 2012 and December 2019 were reviewed and SAS score of each patient was calculated. Relationship between SAS score and postoperative occurrence of delirium were analyzed to determine the underlying mechanism.

Results There are a total of 436 patients included in this study with a mean age of 62.8±13.8 and 61.2±16.8 in each group. Patients in Delirium group had significantly higher incidence of heart failure (P=0.043) preoperatively in the Delirium group. No significant difference was observed referring to ASA PS III (P=0.102) and no significant difference was observed in duration of the surgery and anesthesia. Also no significant differences was observed as to dexmedetomidine and propofol use (P=0.256, P=0.278). The mean SAS score was in 4.2±0.8, 7.8±1.2 in two groups respectively (P¡0.001) and 96(22.02%) postoperative delirium events were recorded. Patients in Delirium group had much more EBL (P¡0.001) while LHR (P=102) showed no significant statistical difference between two groups. Univariate and multivariate regression analysis showed that the intraoperative SAS score was significant predictors of delirium following OPCABG (P¡0.001; P¡0.001). After adjustment for other clinical predictors, the addition of SAS also improved and the area under the curve to predict delirium was 0.934 (95%CI, 0.907-0.960, P¡0.001).

Conclusions Intraoperative SAS score is associated with postoperatively following OPCABG and SAS score may be a valuable component to improve preoperative risk stratification and discrimination of delirium among patient under OPCABG.

Keywords Off-pump coronary artery bypass grafting; Surgical Apgar Score; Delirium; Postoperative; Prediction

Introduction

Off-pump coronary artery bypass grafting (OPCABG) involves the use of a vascular conduit to bypass atheromatous lesions in coronary arteries without the use of cardiopulmonary bypass (CPB) under general anesthesia at lower temperature, and need mechanical ventilation to aid breathing to maintaining oxygen supply to vital organs of the body which is essential for stability of respiratory and circulatory system[1-4]. Be alien to normal heart surgery by CPB, intraoperative anesthesia monitoring in OPCABG is critical to the operation and postoperative morbidities such as myocardial infarction, pulmonary and renal dysfunction, atrial fibrillation, blood transfusion and mental syndromes[5-7]. In patients following OPCABG surgery, manipulation on beating heart and calcified aorta, pain, anxiety and restlessness caused by critically illness, surgical trauma, inflammatory response and a variety of procedures and treatments often discourage the recovery of heart function.

Delirium is a common neuropsychiatric syndrome in the patients following OPCABG surgery.[6,8,9]The hallmark of delirium is acute cognitive disturbance with fluctuation in the level of consciousness and attention. The incidence of delirium in critically ill patients is high. Delirium is particularly problematic in patients receiving heart surgery because it increases the risk of self-extubation and removal of other essential medical devices[10].

Previous studies show that postoperative sedation is important for prognosis. Therefore, the ideal sedative treatment is beneficial to reduce stress response in patients after cardiac surgery, reduce man-machine confrontation, reduce oxygen consumption, stabilize hemodynamics and reduce delirium or restlessness, to ensure the completion of the invasive operation[11-14].

Some prophylactic strategies for the prevention of delirium have been proposed, but not routinely implemented because of the lack of convincing evidence[15]. Surgical Apgar Score (SAS) system was initially validated in patients undergoing general and vascular surgery and was subsequently expanded to a majority of surgical subspecialties[16-21]. SAS relies on three variables (lowest heart rate, lowest mean arterial pressure and estimated blood loss) that are easily obtained from the anesthesia records. There was no study having investigated the association between SAS score and prediction of risk of delirium incidence in patients underwent OPCABG who is at high risk of emotional incidents. This article aims to investigate the predictive value of SAS score on delirium incidence following OPCABG surgery.

Methods

Patient

The study was designed as a retrospective observational study and approval to conduct this study was obtained from Ethics Committee of Shanghai Changhai Hospital. This study included a consecutive series of patients in the department of cardiothoracic surgery center between January 2012 and December 2019 who were underwent OPCABG treatment. Excluded from the study were patients who preoperatively were treated with antipsychotic drugs, and those with a history of mental problem, head injury, neurological dysfunction, patients conversion to CPB and those who underwent emergency operations or reoperations[1,22-25].

Patient management

Medical records and follow-up data of each patient, including the medical history, neurologic examination, operative reports, pathology reports. The SAS was determined from the patient's intraoperative anesthesia chart where blood pressures and heart rates were recorded every 5 minutes, and three intraoperative parameters including estimated blood loss (EBL), lowest mean arterial pressure (LMAP), and lowest heart rate (LHR) were obtained. Follow-up of patients were conducted by contacting patients using telephone or by outpatient clinics[26-29]. Preoperative management, anesthetic, and surgical techniques for all patients were standardized and have been previously reported.

SAS

The SAS score of each patient was calculated from the recorded anaesthesia chart as described previously by Gawande et al[30]. The SAS score is the sum of the points from each category using the above three variables ranges from 0 to 10 points, and the determination of the intraoperative blood loss is based on both the weight of gauze used and the suction used. For patients underwent OPCABG, blood pressure and heart rate were measured invasively and monitored continuously throughout the surgical procedure.

Surgical techniques

All patients underwent OPCABG operation were through a standard median-sternotomy with the left internal mammary artery (LIMA) harvested. Standard anesthetic induction was performed with intravenous propofol or dexmedetomidine, fentanyl, and vecuronium, which was followed by a standard monitoring of arterial catheterization and Swan-Ganz catheter. Heparin was administered to maintain adequate heparinization (ACT, activated clotting time>250seconds). Commercially available mechanical stabilization devices such as the Octopus 2 were used to stabilize the coronary targets on the beating heart and pericardial traction sutures were used where appropriate. Retrograde bleeding was controlled with a sterile, humidified carbon dioxide blower. Distal anastomoses were constructed with a continuous running 7-0 polypropylene suture and proximal anastomoses 6-0 polypropylene suture[1,31-35].

Delirium Assessment

The evaluation of postoperative delirium was conducted by the method of process Confusion Assessment Method for Intensive Care Unit (CAM-ICU), and the trained nurses in the ICU were conducted twice a day at the same time, lasting for 7 days. Delirium was diagnosed as both acute attack and mental state fluctuation and inattention, as well as change of consciousness level or thinking disorder.

Statistical analysis

Statistical analysis was carried out using SPSS 21.0 software. Quantitative data are expressed as mean+-SD and were compared with 2-sample t tests for independent samples, whereas dichotomous variables were reported as absolute values and proportions. Differences in proportion were compared with a $\chi 2$ test or Fisher exact test as appropriate. Univariate analysis was performed with the Kaplan–Meier test and with the Cox regression analysis. For each variable, the odds ratio (OR), 95% confidence interval (CI), and P value were provided. Variables significantly associated with occurrence of delirium event after univariate analysis ($P<0.05$) were entered in a multivariable logistic regression model to identify the independent predictors. Additionally, we calculated the area under receiver operating characteristic (ROC) curve to assess the predictive value of SAS score for risk of delirium in patients following OPCABG.

Results

Characteristics of patients

All enrolled patient's age, gender, medical history, surgery and data related to surgey were collected. A total of 436 patients were included in this study with a mean age of 62.8±13.8 and 61.2±16.8 and comprising 51(53.13%) and 178(52.35%) men in each group. The baseline characteristics of patients with delirium occurred and without delirium were depicted in Table 2. In terms of preoperative symptoms and morbidity, no difference was observed except for the higher incidence of heart failure (P=0.043) in the Delirium group.

Among the surgical procedures, all patients were underwent isolated OPCABG with the help of mechanical stabilization devices, there were no difference in number of distal anastamoses (P=0.068), rate of ITA use (P=0.091) , while patients in Delirium group had a significant higher rate use of radial artery (RA) (P=0.021).

Anaesthesia

Anaesthesia chart were recorded standardly based on the guidelines of Chinese Society of Cardiothoracic and Vascular Anesthesiology and combined intravenous and inhalation anesthesia were used in all patients.

There were no differences with respect to the ASA PS III(American Society of Anesthesiologists Physical Status)(P=0.102) while significantly more ASA PS II patients in Delirium group, no significant difference was observed in duration of the surgery and duration of anesthesia, and preoperative anxiety. There were no significant differences as to dexmedetomidine and propofol use (P=0.256, P=0.278). In Delirium group, patients had significantly more EBL and intraoperative blood transfusion (P¡0.001, P=0.003), and furthermore significantly lower LMAP (P¡0.001) was recorded in Delirium group while no difference was detected as to LHR between two groups (P=0.102). (Table 3).

Perioperative Complications

There was no significant difference in 30-day in-hospital mortality (P=0.072) between two groups, and there was also no significant difference in major bleeding (P=0.065), arrythmia (P=0.089), low cardiac output (P=0.165), as well as the median ICU (intensive care unit, ICU) stay (P=0.319) and hospital stay (P=0.821) between two groups. Postoperative reoperation rate were marginally more common (P=0.041) in Delirium group, and postoperative pulmonary and gastrointestinal complications (P=0.098, P=0.061) were not statistically different between the two groups. MoCA score which is a convenient tool for estimating patients' global cognitive functioning was significantly lower in Delirium group (P=0.001). (Table 4)

Delirium

During the perioperative period, 96(22.02%) postoperative delirium events were recorded and all revealed CAM-ICU evaluation positive. The initiation of delirium events was at a mean 1.87+-0.7 days postoperatively. Postoperative cognition assessed via MoCA score was significantly higher in patients without delirium event occurred (P=0.001). In the assessing process the median pain scores were reduced over time with no statistically significant difference was observed.

Calculation of SAS

The SAS score of each patient was calculated based on intraoperative parameters including EBL, LMAP, and LHR. Comparing to Delirium group, significantly higher LMAP was recorded of patients in no-Delirium group (P¡0.001). Furthermore, patients in Delirium group had much more EBL (P¡0.001) while LHR (P=102) showed no significant statistical difference between two groups. The mean SAS score was in 4.2+-0.8, 7.8+-1.2 in two groups respectively, which showed significantly difference (P¡0.001).

SAS and Delirium

Data of SAS score of patients were presented in Table 3. The incidence rate of delirium was strongly associated with intraoperative SAS score .Patients who developed delirium after OPCABG had significant lower SAS score than those without delirium (P¡0.001), and the univariate and multivariate regression analysis showed that the intraoperative SAS score was significant predictors of delirium following OPCABG (P¡0.001; P¡0.001) (Table 5 and 3).

In the Kaplan-Meier analysis, we stratified SAS score according to previous reports, we categorized SAS score [?]3 as A, 4˜6 as B, 7˜10 C.

As shown in Fig.2, the incidence rate of postoperative delirium was strongly associated with stratification of SAS score and lower stratification of SAS score was predictive of higher delirium incidence rate. The cumulative event rates of delirium in Kaplan-Meier survival curves showed that patients with lower stratification of SAS score had a significant higher incidence rate of delirium (P¡0.001). The predictive value of intraoperative SAS score for incidence of new onset SAS score following OPCABG were depicted in Fig. 3, the area under ROC was 0.934 (95%CI, 0.907-0.960, P¡0.001), which also indicated that delirium score less than 4.5 was independent predictors of delirium.

Discussions

With the update and progress of cardiac surgery technology, OPCABG has been more and more favored by cardiac surgeons. Although the debating of OPCABG and CABG remained, OPCABG has similar survival rate comparing with CABG presently, and it shows great advantages for some older and severe patients[1,2,36-39].

Since OPCABG does not require CPB, related complications such as inflammation and blood cell destruction caused by CPB are avoided. Additionally, in OPCABG surgeons performs coronary artery anastomosis on a beating heart which requires very high surgical skills, and which also poses greater challenges to the cooperation of anesthesiologists whose intraoperative monitoring is vital. Anesthesia for cardiac surgery is more challenging while OPCABG requires much higher for anesthesia. Anesthesiologists must always monitor the vital signs of patients, monitor hemodynamic changes, and cooperate with surgeons' operations at all times intraoperatively. Although diverse anaesthetic and sedative analgesics have been used since modern times, intraoperative complications are still inevitable[40-42].

Delirium is one of the common complications following cardiac surgery. On account of sedation and mechanical ventilation are routinely required after cardiac surgery, and most patients need vasoactive drugs to stabilize vital signs, therefore the occurrence of delirium has threatened the safety of patient postoperatively[6,43-46]. Delirious patients often remove intubation and infusion tubes from the body, which seriously threatens the safety of patients' lives. For the occurrence of postoperative delirium, current research has confirmed many factors including major bleeding during surgery, hemodynamic instability, and the patient's history of cerebrovascular disease[47-51]. However, there is still a lack of a systematic and effective prediction system, thence it is of great significance to explore and study the prediction scoring system for delirium following OPCABG.

The SAS score was mean to be used to assess the prediction of serious complications after general and vascular surgery which includes EBL, LMAP and LHR during anesthesia and shows a good predictive effect. Several research groups noted that the SAS could accurately predict postoperative complications in surgical subspecialties including neurosurgery and esophagectomy[16,52-54]. In another report, stabilizing the vital signs during surgery improved the surgical outcomes in major surgeries. However, whether SAS score has similar predictive effect on the occurrence of delirium following OPCABG, there are few studies at present. Therefore, we though to explore whether the SAS intraoperative score has a good predictive effect on patients following OPCABG.

In the present study, we included patients who underwent OPCABG surgery. The SAS score was calculated by monitoring the patient's anesthesia data during the surgery. The incidence of postoperative delirium was observed through the ICU trained nurses[47,55,56]. Through statistical analysis, we found that low SAS score is an independent risk factor for delirium in OPCABG patients, with EBL and LMAP within the three factors are the main influencing factors. In the prediction model, we found that SAS has a high sensitivity and specificity for predicting the occurrence of postoperative delirium, which has a good warning effect on the prevention of high-risk patients after surgery. In addition, we stratified according to the level of SAS, and found that patients with a low score of 4 have a significantly increased incidence of postoperative delirium, which also provides a good significance for the postoperative monitoring of patients[16,25,29,57]. We thought that because most patients receiving OPCABG have severe coronary calcification, and the vascular elasticity is significantly reduced. Surgical manipulation on beating heart have a greater impact on hemodynamics, usually causing blood pressure fluctuation drastically, and minimum blood pressure may occur between 30-50mmHg. Consequently, the occurrence of hypotension during OPCABG surgery significantly reduced the SAS score[16,58-60]. In addition, although OPCABG does not require CPB, compared with other general surgery, intraoperative blood loss also increased as a result of greater trauma and heparinization. As for changes in heart rate, patients on OPCABG had tachycardia occurred much more than bradycardia because stimulating to the heart. Wherefore, the SAS score during the operation reduced significantly during surgery which can be used to predict postoperative complications such as delirium.

In conclusion, in this retrospective study, we found that for patients underwent OPCABG, the intraoperative SAS score has a useful predictive effect on the occurrence of delirium postoperatively and which shows great correlation with delirium. The main limitation of this study is its retrospective designing and lack of high level of evidence. Secondly, we did not calculate the effect of intraoperative anesthetic and postoperative sedation in this study, and a larger sample size study is expected to draw more persuading conclusions.

References

1. Kuwahara G, Tashiro T. Current Status of Off-Pump Coronary Artery Bypass. *Ann Thorac Cardiovasc Surg.* 2020;26(3):125-132.

2. Yang L, Lin S, Zhang H, et al. Long-Term Graft Patency After Off-Pump and On-Pump Coronary Artery Bypass: A CORONARY Trial Cohort. *Ann Thorac Surg.* 2020.

3. Kowalewski M, Jasinski M, Staromlynski J, et al. On-Pump vs Off-Pump coronary artery bypass surgery

in atrial fibrillation. Analysis from the polish national registry of cardiac surgery procedures (KROK). *PLoS One.*2020;15(4):e0231950.

4. Patel V, Unai S, Gaudino M, Bakaeen F. Current Readings on Outcomes After Off-Pump Coronary Artery Bypass Grafting. *Semin Thorac Cardiovasc Surg.* 2019;31(4):726-733.

5. Kim HJ, Chung JE, Jung JS, Kim IS, Son HS. Current Status of Off-pump Coronary Artery Bypass Grafting in Patients with Multiple Coronary Artery Disease Compared with On-pump Coronary Artery Bypass Grafting: The Korean National Cohort Study. *Thorac Cardiovasc Surg.* 2018;66(6):470-476.

6. Grocott HP. Anesthetic Agents and Postoperative Delirium after Off-pump Coronary Bypass Graft Surgery: An Insufficiently Complex Approach to a Complex Problem. *J Cardiothorac Vasc Anesth.* 2018;32(4):e87-e88.

7. Lerman DA. On- vs. off-pump coronary artery bypass grafting in a heterogeneous patient population. *Ann Transl Med.* 2018;6(3):73.

8. Ma JR, Fan MM, Wang ZS. Age, preoperative higher serum cortisol levels, and lower serum acetylcholine levels predict delirium after percutaneous coronary intervention in acute coronary syndrome patients accompanied with renal dysfunction. *Indian J Psychiatry.* 2020;62(2):172-177.

9. Leenders J, Overdevest E, van Straten B, Golab H. The influence of oxygen delivery during cardiopulmonary bypass on the incidence of delirium in CABG patients; a retrospective study. *Perfusion.* 2018;33(8):656-662.

10. Szwed K, Pawliszak W, Szwed M, Tomaszewska M, Anisimowicz L, Borkowska A. Reducing delirium and cognitive dysfunction after off-pump coronary bypass: A randomized trial. *J Thorac Cardiovasc Surg.* 2019.

11. Raja SG, Garg S, Soni MK, et al. On-pump and off-pump coronary artery bypass grafting for patients needing at least two grafts: comparative outcomes at 20 years. *Eur J Cardiothorac Surg.* 2020;57(3):512-519.

12. Sleigh JW, Gaskell A. Postoperative Delirium: A Minefield of Markers and Mediators. *Anesthesiology.* 2020.

13. Delp S, Mei W, Spies CD, et al. Clinical practice in the management of postoperative delirium by Chinese anesthesiologists: a cross-sectional survey designed by the European Society of Anaesthesiology. *J Int Med Res.*2020;48(6):300060520927207.

14. Flier S, Post J, Concepcion AN, Kappen TH, Kalkman CJ, Buhre WF. Influence of propofol-opioid vs isoflurane-opioid anaesthesia on postoperative troponin release in patients undergoing coronary artery bypass grafting. *Br J Anaesth.* 2010;105(2):122-130.

15. Saller T, Peterss S, Scheiermann P, et al. Natriuretic Peptides as a Prognostic Marker for Delirium in Cardiac Surgery-A Pilot Study. *Medicina (Kaunas).* 2020;56(6).

16. Bhandoria G, Mane JD. Can Surgical Apgar Score (SAS) Predict Postoperative Complications in Patients Undergoing Gynecologic Oncological Surgery? *Indian J Surg Oncol.* 2020;11(1):60-65.

17. Hu WP, Yang YS, Yuan Y, Wang WP, Shang QX, Chen LQ. How does Surgical Apgar Score predict the short-term complications and long-term prognosis after esophagectomy? *J Thorac Dis.* 2019;11(Suppl 3):S268-S270.

18. Liu R, Kidane B. Esophagectomy Surgical Apgar Score: One Size Fits All? *Semin Thorac Cardiovasc Surg.* 2019;31(3):581-582.

19. Day KE, Prince AC, Lin CP, Greene BJ, Carroll WR. Utility of the Modified Surgical Apgar Score in a Head and Neck Cancer Population. *Otolaryngol Head Neck Surg.*2018;159(1):68-75.

20. Nair A, Bharuka A, Rayani BK. The Reliability of Surgical Apgar Score in Predicting Immediate and Late Postoperative Morbidity and Mortality: A Narrative Review. *Rambam Maimonides Med J.* 2018;9(1).

21. Yoshida N, Baba H. Clinical usefulness of the surgical Apgar score for estimating short-term and prognostic outcomes after esophagectomy. *J Thorac Dis.*2018;10(Suppl 18):S2103-S2105.

22. Haessler R, Schwender D, Leppmeier U, Klasing S, Rindfleisch F, Peter K. Anaesthesia for coronary artery bypass grafting: opioid-analgesia combined with either flunitrazepam, propofol or isoflurane. *Acta Anaesthesiol Scand.*1993;37(6):532-540.

23. Zi J, Fan Y, Dong C, Zhao Y, Li D, Tan Q. Anxiety Administrated by Dexmedetomidine to Prevent New-Onset of Postoperative Atrial Fibrillation in Patients Undergoing Off-Pump Coronary Artery Bypass Graft. *Int Heart J.* 2020;61(2):263-272.

24. Takagi H, Hari Y, Mitta S, Kawai N, Ando T, Group A. A meta-analysis of >/=5-year mortality in randomized controlled trials of off-pump versus on-pump coronary artery bypass grafting. *J Card Surg.* 2018;33(11):716-724.

25. Haddow JB, Adwan H, Clark SE, et al. Use of the surgical Apgar score to guide postoperative care.*Ann R Coll Surg Engl.* 2014;96(5):352-358.

26. Pearson ACS, Subramanian A, Schroeder DR, Findlay JY. Adapting the Surgical Apgar Score for Perioperative Outcome Prediction in Liver Transplantation: A Retrospective Study. *Transplant Direct.* 2017;3(11):e221.

27. Prasad SM, Ferreria M, Berry AM, et al. Surgical apgar outcome score: perioperative risk assessment for radical cystectomy. *J Urol.* 2009;181(3):1046-1052; discussion 1052-1043.

28. Kotera A. The Surgical Apgar Score can help predict postoperative complications in femoral neck fracture patients: a 6-year retrospective cohort study. *JA Clin Rep.* 2018;4(1):67.

29. Aoyama T, Kazama K, Murakawa M, et al. The Surgical Apgar Score Is an Independent Prognostic Factor in Patients with Pancreatic Cancer Undergoing Pancreatoduodenectomy Followed by Adjuvant Chemotherapy. *Anticancer Res.*2016;36(5):2497-2503.

30. Haynes AB, Regenbogen SE, Weiser TG, et al. Surgical outcome measurement for a global patient population: validation of the Surgical Apgar Score in 8 countries. *Surgery.*2011;149(4):519-524.

31. Okano R, Liou YJ, Yu HY, et al. Coronary Artery Bypass in Young Patients-On or Off-Pump? *J Clin Med.* 2019;8(2).

32. Ramponi F, Seco M, Edelman JB, et al. Dual inflow, total-arterial, anaortic, off-pump coronary artery bypass grafting: how to do it. *Ann Cardiothorac Surg.*2018;7(4):552-560.

33. Ammannaya GKK, Basantwani S, Mishra P, Khandekar JV. Effect of octopus tissue stabilizer on cardiac output during off-pump coronary artery bypass graft surgery.*Kardiochir Torakochirurgia Pol.* 2019;16(2):69-73.

34. Xie HT, Kang XQ, Zhang S, Tian YC, Liu DJ, Bai BJ. Effects of on-pump versus off-pump coronary artery bypass grafting on myocardial metabolism. *Medicine (Baltimore).*2019;98(17):e15351.

35. Diegeler A, Borgermann J, Kappert U, et al. Five-Year Outcome After Off-Pump or On-Pump Coronary Artery Bypass Grafting in Elderly Patients. *Circulation.*2019;139(16):1865-1871.

36. Vrancic JM, Cervetti MR, Benavides J, Navia D. Off-Pump Coronary Revascularization Using Bilateral Internal Thoracic Arteries in A Patient with Paroxysmal Nocturnal Hemoglobinuria: A Case Report. *Braz J Cardiovasc Surg.*2019;34(4):488-490.

37. Benedetto U, Puskas J, Kappetein AP, et al. Off-Pump Versus On-Pump Bypass Surgery for Left Main Coronary Artery Disease. *J Am Coll Cardiol.* 2019;74(6):729-740.

38. Ramakrishna H. Off-Pump Versus On-Pump Coronary Artery Bypass Grafting: Should This Debate Even Continue? *J Cardiothorac Vasc Anesth.* 2019;33(5):1195-1196.

39. Yuan B, Qi HW, Zhao JG, et al. Total Arterial Off-Pump Coronary Artery Bypass Grafting: A 10-Year Experience. *Chin Med J (Engl).* 2018;131(18):2179-2184.

40. Streisand JB, Wong KC. Anaesthesia for coronary artery bypass graft. *Br J Anaesth.*1988;61(1):97-104.

41. Roby HP, Harrison GA. Anaesthesia for coronary artery bypass in a patient with porphyria variegata.*Anaesth Intensive Care.* 1982;10(3):276-278.

42. Zimbler N, Ashley EM. Anaesthesia for coronary artery bypass: should it differ off-pump and on-pump?*Hosp Med.* 2003;64(9):564.

43. Harshe D, Nagda P, Gore S. Delirium after abrupt discontinuation of clozapnie. *Asian J Psychiatr.* 2020;53:102235.

44. Vasunilashorn SM, Schulman-Green D, Tommet D, et al. New Delirium Severity Indicators: Generation and Internal Validation in the Better Assessment of Illness (BASIL) Study.*Dement Geriatr Cogn Disord.* 2020:1-17.

45. Cipriani G, Danti S, Nuti A, Carlesi C, Lucetti C, Di Fiorino M. A complication of coronavirus disease 2019: delirium. *Acta Neurol Belg.* 2020.

46. Grover S, Kumar A, Chakrabarti S, Avasthi A. The incidence of prolonged post-electroconvulsive therapy delirium: A retrospective study. *Indian J Psychiatry.*2020;62(2):193-197.

47. Choi JS, Oh SJ, Sung YW, Moon HJ, Lee JS. Pulse wave velocity is a new predictor of acute kidney injury development after off-pump coronary artery bypass grafting. *PLoS One.* 2020;15(4):e0232377.

48. Gomez Tovar LO, Henao Castano AM. Analysis of Delirium From the Dynamic Symptoms Model: A Literature Review. *Crit Care Nurs Q.* 2020;43(3):312-336.

49. Falsini G, Romanelli S, Insana L, et al. [Delirium in cardiology: an old problem, a new emergency].*G Ital Cardiol (Rome).* 2020;21(6):434-446.

50. Myles PS. Evaluating interventions to reduce the risk of postoperative delirium. *Br J Anaesth.* 2020;125(1):4-6.

51. Kim DJ, Lee SH, Joo HC, Yoo KJ, Youn YN. Effects of a Proximal Seal System on Neurologic Outcomes of Off-Pump Coronary Artery Bypass Grafting. *Int Heart J.*2019;60(3):593-600.

52. Mastalerz K, Kenig J, Olszewska U, Michalik C. The Surgical Apgar Score and frailty as outcome predictors in short- and long-term evaluation of fit and frail older patients undergoing elective laparoscopic cholecystectomy - a prospective cohort study. *Wideochir Inne Tech Maloinwazyjne.*2018;13(3):350-357.

53. Park SH, Lee JY, Nam EJ, Kim S, Kim SW, Kim YT. Prediction of perioperative complications after robotic-assisted radical hysterectomy for cervical cancer using the modified surgical Apgar score. *BMC Cancer.* 2018;18(1):908.

54. Li S, Zhou K, Li P, Che G. Is surgical Apgar score an effective assessment tool for the prediction of postoperative complications in patients undergoing oesophagectomy?*Interact Cardiovasc Thorac Surg.* 2018;27(5):686-691.

55. Hunter A, Crouch B, Webster N, Platt B. Delirium screening in the intensive care unit using emerging QEEG techniques: A pilot study. *AIMS Neurosci.* 2020;7(1):1-16.

56. Chang HCR, Neal K, Traynor V, Ho MH, Kankom W. Delirium Among Hospitalized Older Adults in Thailand: An Integrative Review. *J Gerontol Nurs.* 2020;46(6):43-52.

57. Melis M, Pinna A, Okochi S, et al. Validation of the Surgical Apgar Score in a veteran population undergoing general surgery. *J Am Coll Surg.* 2014;218(2):218-225.

58. Lindroth H, Khan BA, Carpenter JS, et al. Delirium Severity Trajectories and Outcomes in ICU Patients: Defining a Dynamic Symptom Phenotype. *Ann Am Thorac Soc.* 2020.

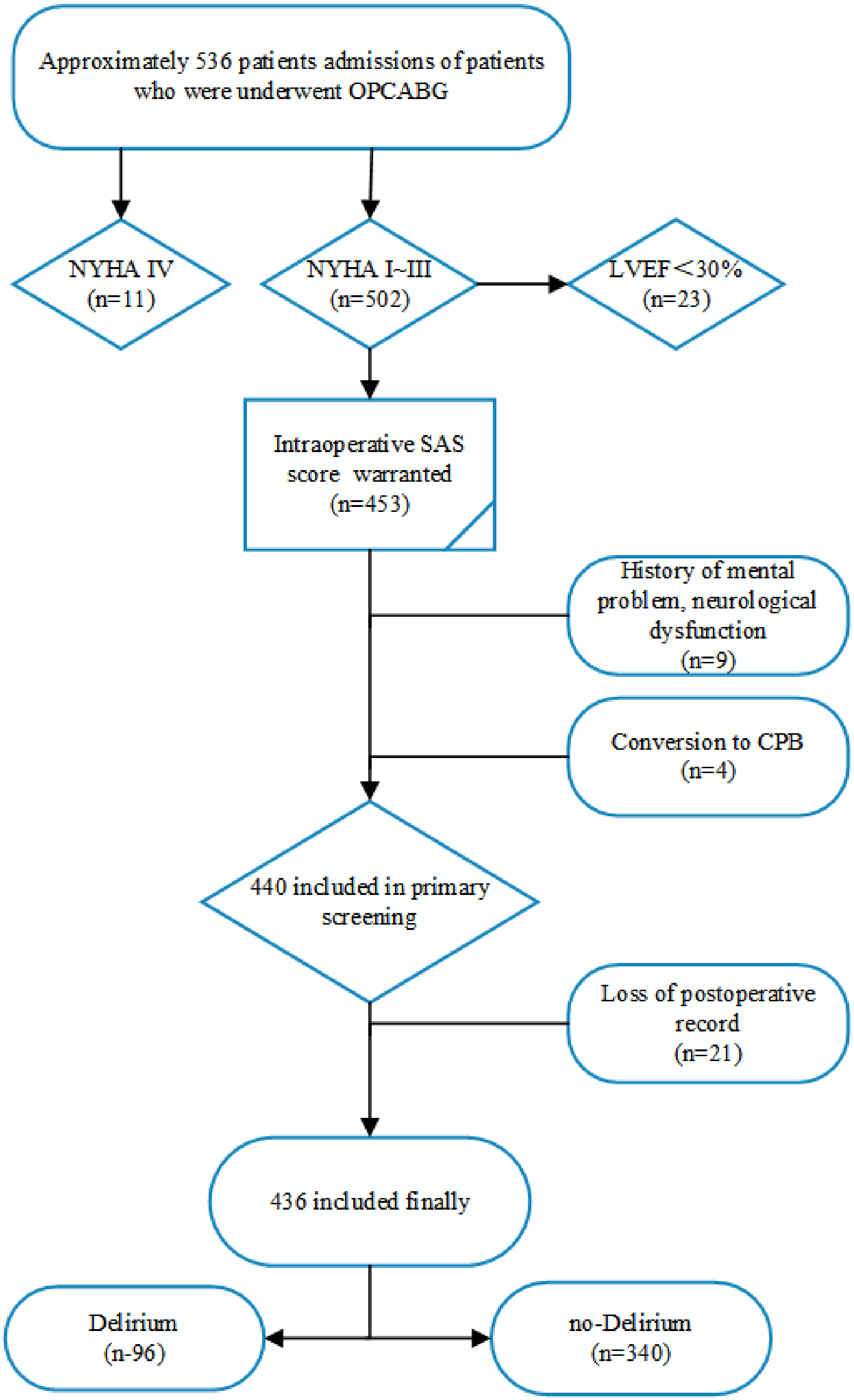
59. Ngarambe C, Smart BJ, Nagarajan N, Rickard J. Validation of the Surgical Apgar Score After Laparotomy at a Tertiary Referral Hospital in Rwanda. *World J Surg.*2017;41(7):1734-1742.

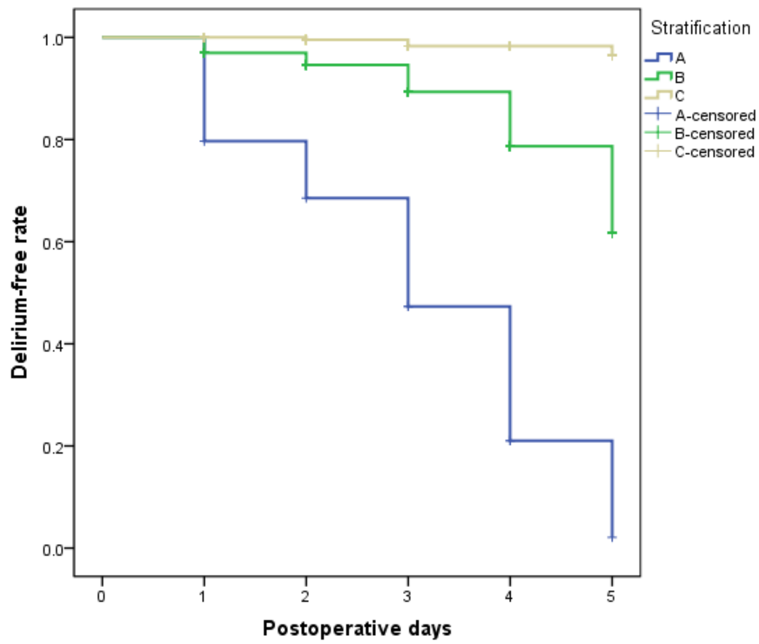
60. Orberger M, Palisaar J, Roghmann F, et al. Association between the Surgical Apgar Score and Perioperative Complications after Radical Prostatectomy. *Urol Int.*2017;98(1):61-70.

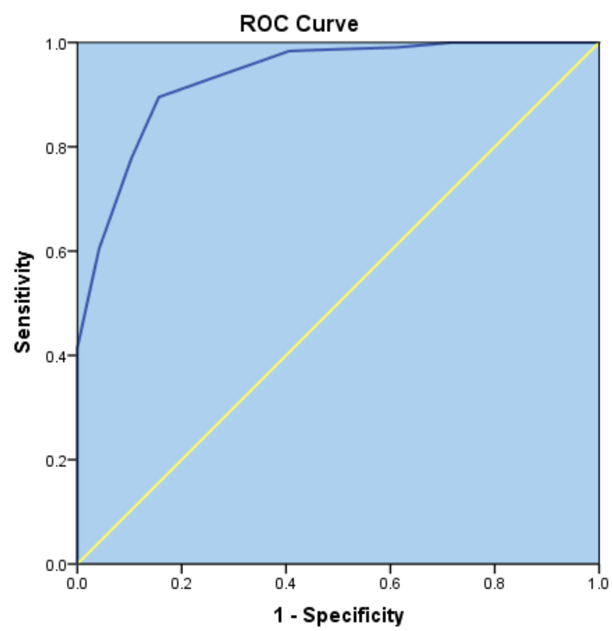
Fig. 1. Flowchart diagram of patient assessment and selection.

Fig. 2. Delirium incidence rates and stratifications of SAS score. The delirium incidence rates are higher in higher stratification of SAS score, and the incidence of delirium incrementally increased with stratification of SAS score.

Fig. 3. Predictive value of SAS score for incidence of delirium following OPCABG under ROC. The area under ROC was the area under ROC was 0.934 (95%CI, 0.907-0.960, P¡0.001).


Approximately 536 patients admissions of patients who were underwent OPCABG
NYHA IV (n=11)
NYHA I~III (n=502)
LVEF＜30% (n=23)
Intraoperative SAS score warranted (n=453)
History of mental problem, neurological dysfunction (n=9)
Conversion to CPB (n=4)
440 included in primary screening
Loss of postoperative record (n=21)
436 included finally
Delirium (n-96)
no-Delirium (n=340)





Diagonal segments are produced by ties.

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