Cardiopulmonary Bypass Complications in a West African Country (Senegal)

Abdel-Kémal Bori Bata1, *, Amadou Gabriel Ciss1, Momar Sokhna Diop1, Papa Salmâne Ba1, Papa Amath Diagne1, Ndeye Fatou Sow1, Gaye Magaye1, Souleyman Diatta1, Mohamed Leye2, Etienne Birame Sene3, Diene Samba1, Papa Adama Dieng1, Assane Ndiaye1, Mouhamadou Ndiaye1

1Department of Thoracic and Cardiovascular Surgery Fann University Hospital, Dakar, Senegal
2Department of Cardiology Fann University Hospital, Dakar, Senegal
3Department of Anesthesiology Fann University Hospital, Dakar, Senegal

Email address:
bbak@live.fr (Abdel-Kémal B. B.), cissgaby@yahoo.fr (A. G. Ciss.), momarsokhna08@yahoo.fr (M. S. Diop), mansalb@yahoo.fr (P. S. Ba), diagnepapaamath@gmail.com (P. A. Diagne), zenefes@gmail.com (N. F. Sow), mgaye99@yahoo.fr (G. Magaye), soul.diatta@yahoo.fr (S. Diatta), leyemohamed@gmail.com (M. Leye), biramsene@hotmail.com (E. B. Sene), sdiene@gmail.com (D. Samba), padiengsala@yahoo.fr (P. A. Dieng), lazanat@yahoo.fr (A. Ndiaye), mondiaye@orange.sn (M. Ndiaye)

*Corresponding author

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Abstract: Although cardiopulmonary bypass (CPB) has simplified open heart surgery, it causes adverse effects on the body's systems. This study aims to report the complications related to CPB at the Cardiac Surgery Center of the University Hospital in Dakar (Senegal). This is a retrospective analytical and descriptive study covering a 24 months period (from January 2015 to December 2016). All adult and children patients who underwent open heart surgery using CPB machines were included in this study. 193 patients were eligible during this study's period. Patients' mean age was 23 ± 15 years (range, 2–65), and 52% were female patients. Two complications were observed during CPB. One case of hemolysis and one case of an impossible weaning from CPB. Post-CPB complications were allocated as follows: hematological complications (88.5%) followed by cardiovascular (56%), pleuropulmonary (22.4%), septicemia (4%), renal (3%), systemic inflammatory response syndrome (SIRS) (2%) and neurologic (1%) complications. The overall hospital mortality was 5%. One (1) patient died intra operatively and nine (9) patients in the intensive care unit. The morbidity and mortality related to CPB in our cardiac surgery center is superimposed to those of the literature.

Keywords: Cardiopulmonary Bypass, Complications, Open Heart Surgery

1. Introduction

Cardiopulmonary bypass (CPB) is a blood circulation external derivation technique during which the cardiac and pulmonary functions are temporarily assured by a mechanical system connected to the vascular system of the patient. The CPB is the machine that allows surgeons to operate on a nonmoving, bloodless heart. The first successful series of open-heart surgery utilizing CPB machines occurred in 1953 by John Gibbon [1]. Nowadays, and throughout the world, the use of the CPB machine during cardiac surgery has become a widely employed practice. However, open heart surgery (OHS) has only recently been introduced in Africa; in Sub-Saharan Africa, it started in the 70’s. The first OHS in the West African sub region was performed in Nigeria in 1974; in Senegal, it was performed 1996. [2, 3]

Although CPB has simplified open heart surgery, it also causes adverse effects on a body systems, including
complications of the inflammatory system, heart, lungs, kidneys, and brain.

The aim of this study is to report the complications related to CPB at the Cardiac Surgery Center of the University Hospital of Fann in Dakar (Senegal).

2. Method

This is a retrospective analytical and descriptive study covering a 24 months period (from January 2015 to December 2016).

2.1. Inclusion et Exclusion Criteria

All adult and children patients who underwent OHS using CPB machine were included in this study.

One hundred ninety-three (193) patients were eligible during this period. The clinical characteristics of all patients are listed in table 1. The patients had no preoperative biological abnormality. Preoperative diagnoses are listed in table 2.

| Characteristics                      | Values                  |
|--------------------------------------|-------------------------|
| Age Mean ± SD years [range]          | 23 ± 15 [2–65]          |
| BMI Mean ± SD [range]                | 18 ± 4.4 [9–35]         |
| Sex Female                           | 52%                     |
| Previous cardiac surgery             | 4%                      |
| Comorbidities (frequency)            |                         |
| Ischemic stroke                      | 4                       |
| Down's Syndrome                     | 2                       |
| High blood pressure                  | 1                       |
| New York Heart Association class     |                         |
| Absence or NYHA I                    | 1.5%                    |
| NYHA II                              | 71%                     |
| NYHA III                             | 27.5%                   |
| Electrocardiogram                    |                         |
| Normal sinus rhythm                  | 81%                     |
| AAF                                  | 16%                     |
| Other (atrial flutter, atrial fibrillation) | 3%                   |
| Chest X-ray                          |                         |
| Indirect sign of PAH                 | 60%                     |
| Hemoglobin Mean ± SD [range]         | 13.4 ± 2.5 g/dL [7–25]  |
| Hemoglobin < 12g/dL                  | 22%                     |
| Hematocrit Mean ± SD [range]         | 39.3 ± 8.3% [20-80]     |
| Transesophageal echocardiography     |                         |
| PAH                                  | 58%                     |
| Left atrial enlargement              | 60%                     |
| sPAP                                 | 63 ± 19 mm [38-123]     |
| LVEF                                 | 65% ± 9 mm [40-87]      |
| Tricuspid regurgitation              | 49%                     |
| Grade I                              | 18%                     |
| Grade II                             | 49%                     |
| Grade III                            | 18%                     |
| Grade IV                             | 15%                     |

BMI: body mass index; SD: standard deviations; PAP: systolic pulmonary artery pressure.
PAH: pulmonary arterial hypertension; AAF: Arrhythmia Atrial fibrillation.

| Diagnoses                          | Frequency | Percentage |
|------------------------------------|-----------|------------|
| Mitral regurgitation               | 44        | 22.8       |
| Mixed mitral disease               | 29        | 15         |
| Mitral stenosis                    | 34        | 17.6       |

| Diagnoses                          | Frequency | Percentage |
|------------------------------------|-----------|------------|
| Aortic regurgitation               | 7         | 3.6        |
| Mixed aortic disease               | 4         | 2.1        |
| Aortic stenosis                    | 2         | 1          |
| Tetralogy of Fallot                | 23        | 11.9       |
| Atrial septal defect               | 19        | 9.8        |
| Ventricular septal defect          | 13        | 6.7        |
| Subaortic diaphragm                | 12        | 6.1        |
| Atrioventricular Canal defect      | 3         | 1.5        |
| Pulmonary infundibular stenosis    | 1         | 0.5        |
| Left Atrial Myxoma                 | 1         | 0.5        |
| Pentality of Fallot                | 1         | 0.5        |

2.2. Statistical Methods

All analyses were conducted with IBM® SPSS® Statistics Version 22 under a bilateral hypothesis with a type-I error set at 5%. For descriptive analyses, the categorical variables were expressed as number and percentage; the quantitative variables were expressed as mean ± standard deviation (SD) in case of Gaussian distribution, or by quartiles and range otherwise.

2.3. Surgery

The CPB had been established using ascending aorta and bicaval cannulations in 90% of cases. In other cases, the aortic cannulation was associated with a single cannulation of the right atrium with a “two-stage” cavoatrial cannula. Heparin-coated circuits were used in all cases. The anticoagulation was performed with heparin. The priming volume contained heparin in 84% of cases with a mean of 8092 ± 3740 IU (range, 1000–15000). By adding the dose of heparin in the priming and that administered parenterally; the mean total dose of heparin was 26167 ± 9720 IU (range, 6000–45000). No cases of heparin resistance have been reported. The mean ACT (Activated clotting time) before starting CPB was 506 ± 167 seconds (sec) (range, 320–1443). During CPB, the mean of minimum ACT was 436 ± 134 sec, the mean of maximum ACT was 561 ±179 sec. No cardiotomy filter was replaced. The surgical procedures are listed in table 3. Operative data of the patients are listed in table 4. Cross clamp times was superior to 120 minutes (min) in 7 cases. The resumption of cardiac activity had occurred in normal sinus rhythm (74.5%), ventricular fibrillation (14.5%), atrioventricular block (AVB) (8.3%). Intra operative hemodynamic status was stable under vasoactive drug in 31% of cases.

| Diagnoses                          | Frequency | Percentage |
|------------------------------------|-----------|------------|
| Mitral valve replacement           | 26        |            |
| Mitral valve replacement + Tricuspid valve repair | 17    |            |
| Aortic valve replacement           | 8         |            |
| Mitral valve replacement + Aortic valve replacement | 6      |            |
| Mitral valve repair                | 5         |            |
| Tetralogy of Fallot correction     | 12        |            |
| Correction of atrial septal defect  | 10        |            |
| Correction of ventricular septal defect | 7      |            |
| Resection of subaortic diaphragm    | 6         |            |
| Correction Atrioventricular septal defect | 1.5 |            |
| Pentality of Fallot correction     | 0.5       |            |
| Correction of pulmonary infundibular stenosis | 0.5 |            |
| Resection of left atrial myxoma     | 0.5       |            |
Table 4. Operative data.

| Operative characteristics | Values |
|---------------------------|--------|
| Aortic cannula            | Size: Mean ± SD [range] 18 ± 3 F [10-22] |
| Inferior vena cava cannula| 27 ± 6 F [14 -34] |
| Superior vena cava cannula| 26 ± 6 F [12–40] |
| Priming                   | Crystallloid 93% |
| Blood                     | 7% |
| Cardioplegia              | Crystallloid 69.4% |
|                          | Cold blood 28.5% |
|                          | Warm blood 2% |
| Central temperature       | Mild hypothermia 32% |
|                          | Moderate hypothermia 32% |
|                          | Normothermia 36% |
| CPB Time                  | Mean ± SD [range] 90 ± 34min [26–343] |
| Cross clamp time          | Mean ± SD [range] 66.3 ± 28.5 min [18–214] |
| Minimum Hematocrit during CPB | 28.4 ± 6% [14–46] |
| Hemofiltration (the usage rate of) | 63% |
| UF conventionnelle        | 94% |
| UF + MUF                  | 5% |
| MUF                       | 1% |
| Flow of CPB               | Mean ± SD [range] 3.1 ± 0.8 l/min/m² [0.9–5.5] |
| Mean arterial pressure    | Mean ± SD [range] 60.4 ± 9.3mmHg [40–80] |
| Diuresis during CPB       | 286.3 ± 290 ml [10–1800] |

F: French; min: minutes; UF: ultrafiltration; MUF: Modified ultrafiltration.

3. Results

Two complications were observed during CPB. One case of hemolysis due to an accident of blood transfusion via the CPB circuit because an inappropriate blood type had been transfused. The second complication was an impossible weaning from CPB. The patient died intra operatively after a voluntary stoppage of CPB assistance. After a CPB time of 343 min, cross clamp time of 214 min and CPB assistance of 120 min. It was a 19-year-old patient operated for a mitral and aortic valve replacement. We did not have an extracorporeal life support device.

Post-CPB complications are listed in table 5. No case of allergic reactions to protamine sulfate and heparin-induced thrombocytopenia had been reported.

Table 5. Post-cardiopulmonary bypass complications.

| Complications                                      | Values                          |
|----------------------------------------------------|---------------------------------|
| Hematological                                      | 88.5%                           |
| Anemia (hemoglobin <10g/dL)                        | 43.5%                           |
| Hemoglobin: Mean ± SD [range]                      | 8.5 ± 1.1g/dL [5–9,9]           |
| Hyperleukocytosis (>10000 mm⁻³)                    | 56%                             |
| Leukocytes: Mean ± SD [range]                      | 17123 ± 4854 cells/mm⁻³ [11100-30400] |
| Low level of prothrombin ratio                    | 62%                             |
| Prothrombin Ratio: Mean ± SD [range]               | 48 ± 9% [14-63]                 |
| Thrombocytopenia                                   | 25%                             |
| Platelets: Mean ± SD [range]                       | 102277 ± 34355 cells/mm⁻³ [12000-14800] |
| Hemolysis                                          | 0.5%                            |
| Surgical bleeding                                  | 1%                              |
| Biological bleeding                                | 11%                             |
| Reoperation                                        | 4%                              |
| Reoperation for biological bleeding                | 2%                              |
| Reoperation for surgical bleeding                  | 1%                              |
| Reoperation for accidental removal of temporary electrode epicardials pacing | 0.5% |
| Cardiovascular                                     | 56%                             |
| Right Ventricular Dysfunction                      | 52%                             |
| TAPSE: Mean ± SD [range]                           | 9.5 ± 2.5 mm [4–14]             |
| Left Ventricular Dysfunction                       | 15.5%                           |
| LVEF: Mean ± SD [range]                            | 40 ± 5.6% [25–45]               |
| PAH                                                | 12.4%                           |
| sPAP: Mean ± SD [range]                            | 55 ± 18.4 mmHg [38–104]         |
| Others: (AVB, arrhythmia, AF…)                     | 8.5%                            |
| Pleuropulmonary                                    | 22.4%                           |
The overall hospital mortality was 5% (10 cases). One (1) patient died intra operatively and nine (9) patients in the ICU (intensive care unit). Cause of death was multiple organ failures (4 cases), right ventricular dysfunction associated with pulmonary arterial hypertension (3 cases), septic shock associated with AVB (1 case), bleeding caused by disunity of superior vena cava suture line (1 case). The mean length of stay in the ICU was 3.8 ± 2 days (range, 2–18).

4. Discussion

Complications after use of cardiopulmonary bypass are common. Acute accidents and incidents occurring during CPB are in the order of 0.4 –1% [4]. It was in order of 1% in our series. Apart from a blood transfusion accident via the CPB circuit, the second complication was an impossible weaning from CPB. This case required cardiopulmonary support for failure to wean from CPB. However, we did not have an extracorporeal life support device. Predictors of difficult weaning from CPB are: prolonged aortic cross clamp time > 60 minutes, prolonged bypass time, poor myocardial preservation during CPB, prebypass Delta PCO$_2$ > 6 mmhg, preoperative diastolic dysfunction, PAH (pulmonary arterial hypertension) [5].

Post-CPB complications were dominated by hematological complications. Postoperative anemia (43.5%), hyperleukocytosis (56%), low level of prothrombin ratio (62%) and thrombocytopenia (25%) were the most prevalent. In the literature, the rate of anemia post-CPB range from 48 to 51% [6], the mean hemoglobin post-CPB ranges from 9.3 to 11g/dL, the ratio of thrombocytopenia ranges from 35 to 65% [8]. The postoperative anemia increases postoperative morbidity or the length of the hospital stay [7]. Lako et al. reported 90.2% of the patients with neutrophilic leukocytosis and the maximal level of the leucocytes was 34.170 mm$^3$ [7].

Cardiovascular complications were dominated by right ventricular dysfunction (RVD) (52%) followed by left ventricular dysfunction (LVD) (15.5%) and PAH (12.4%). RVD are traditionally described after OHS and evaluated by TAPSE. In the literature, the post-CPB TAPSE ranges from 11 to 18 mm and is correlated with CPB time [9, 10]. LVD after CPB is well known; the LVEF post-CPB ranges from 38 to 59% [10]. However, LVD is transitional with a recovery within 48 hours. PAH are predictors of difficult weaning from CPB, but also have an impact on mortality and RV function [5, 11].

In the literature, pleuropulmonary complications range from 8 to 79% [12]. In our series, these complications were dominated by bronchopneumonia (16%); they range from 2 to 22% in the literature. The rate of pleural effusion ranges from 24 to 95%, that of pneumothorax ranges from 0.7 to 5.3, ARDS (acute respiratory distress syndrome) ranges from 0.4 to 2% [12].

Acute kidney injury post-CPB was in the order of 3% in our series; it ranges from 2 to 40% in the literature [12, 13]. Hemodilution during CPB, anemia and peri operative blood transfusion are factors that contribute to acute kidney injury [14]. Neurologic complications were in the order of 1% in our series; it ranges from 1 to 2% in the low-risk patients and 6 to 8% in the high-risk patients. The rate of SIRS ranges from 10 to 11% in the literature. [12]

Our rate of hepatosplanchnic complications has been overestimated because of biological hepatic cytolysis that was often asymptomatic. Therefore, by ignoring biological hepatic cytolysis the rate of hepatosplanchnic complications would become 3.6%.

In our series, the mean length of stay in the ICU was 3.8. In the literature, it ranges from 1 to 4 days. Five predictors of prolonged ICU stay were identified: ejection fraction < 30%, PAH, prolonged ventilation (≥ 12 hours), number of blood units transfused, and postoperative acute renal failure. Hospital mortality ranges from 2 to 4.6% in the literature. [15]

5. Conclusion

The morbidity and mortality related to CPB in our cardiac

| Complications                                      | Values          |
|---------------------------------------------------|-----------------|
| Bronchopneumonia                                  | 16%             |
| Pleural effusion                                  | 5%              |
| Pneumothorax                                      | 3%              |
| Atelectasis and ARDS                              | 1%              |
| Hepatosplanchnic                                 | 18%             |
| Biological hepatic cytolysis (often asymptomatic) | 16%             |
| ASA T: Mean ± SD [range]                          | 114 ± 50 mmol/L [58–262]. |
| Functional Intestinal Obstruction                 | 2.6%            |
| Diarrhea and dyspepsia                            | 1%              |
| Renal                                             | 3%              |
| Acute kidney injury                               | 3%              |
| Neurologic                                        | 1%              |
| Ischemic stroke                                   | 0.5%            |
| Anoxic encephalopathy                             | 0.5%            |
| Septicemia                                        | 4%              |
| SIRS                                              | 2%              |
surgery center is superimposed to those of the literature. Post-CPB complications were dominated by hematological complications followed by cardiovascular and pulmonary complications. Anemia was the most prevalent of hematological complications. Cardiovascular complications were dominated by RVD followed by LVD. Pleuropulmonary complications were dominated by bronchopneumonia. Renal complications were represented by acute kidney injury. However, by improving care and monitoring in intensive care unit; we could reduce our morbidity and mortality.

Competing Interests
The authors declare there is no conflict of interest.

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