Successful Management of Membrane Oxygenator Failure during Cardiopulmonary Bypass—The Importance of Safety Algorithm and Simulation Drills

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Abstract: With a high risk to time ratio, the advent of cardiopulmonary bypass has facilitated greater advances in technical procedures in cardiac surgery. This, however, has not come without its own complication risk and previous near misses have been reported with regard to various technical aspects of the cardiopulmonary bypass circuit. We present a case of a failed membrane oxygenator and discuss the real-life aspects to managing this complication without added risk to the patient. Keywords: membrane oxygenator, cardiopulmonary bypass.

Cardiopulmonary bypass (CPB) is an essential component of modern cardiac surgery. However, equipment failure can occur with any advanced technology and in the case of cardiopulmonary bypass, is potentially lethal. We report a case in which a membrane oxygenator failure was discovered during surgery. The successful management of this scenario was described.

DESCRIPTION

A 61-year-old man with a history of previous coronary artery bypass surgery presented with nonST elevation myocardial infarction and post infarct angina. Investigation revealed stenosis of the previous bypass graft and severe native coronary artery disease. The patient was scheduled for urgent redo coronary artery bypass grafting. Following routine anesthesia, uneventful redo sternotomy, and dissection of the heart, cardiopulmonary bypass was instituted using direct ascending aortic cannulation and cannulation of the right atrium with a 2-stage venous cannula. Forty-one minutes after commencement of CPB, a rise in the partial pressure of carbon dioxide (pCO2) was noted (8.35 kPa) by the perfusionist. This had risen from 5.10 kPa at the commencement of CPB. The patient had no known history of lung disease and was a lifelong non-smoker. Suspicion of membrane oxygenator failure was raised with the differential diagnosis of malignant hyperthermia.

Malignant hyperthermia was ruled out on the basis that the patient was normothermic, was not hypoxic, and had good muscular tone. Moreover, intravenous muscle relaxants and volatile anesthetic agents had been terminated with the commencement of CPB.

We then elected to replace the assumed failed Sorin PrimO2X membrane oxygenator (Sorin Group, Arvada, CO) (Figure 1). To prepare for this, the patient was cooled to 28°C as measured on the nasopharyngeal and bladder temperature probe. Intravenous dexamethasone and thiopentone was administered by the anesthetist and the ice pack was applied to the patient’s head. Once these maneuvers were performed, CPB was terminated and the membrane oxygenator replaced by two staff perfusionists following strict departmental protocol. The recorded change over time was 2 minutes. Following replacement of the membrane oxygenator, the pCO2 returned to 4.93 kPa and remained within the acceptable range for the rest of the procedure (Table 1). The remaining operation was uncomplicated. The patient had an uneventful recovery and was discharged on the seventh post-operative day.

COMMENT

Cardiopulmonary bypass is an essential component of modern cardiac surgery. Since its initial development, the
Heart lung machine has become more sophisticated as technology has advanced. However, the use of CPB, with its various mechanical components, has the potential to fail. When this occurs, it is potentially lethal. Therefore, perfusion safety is paramount and encompasses many facets including equipment, safety devices, conduct of perfusion, surgical technique, vigilance, and communication in the operating room. Management of failure of CPB components will therefore require coherent input from every member of the team with adherence to a strict algorithm to solve the problem (1,2).

Failure of the oxygenator during CPB is rare. In the United States, 50 cases have been reported in 2009, 101 cases in 2010, and 133 cases in 2011 to the Manufacturer and Users Device Experience website. In the literature, Webb et al. reported one such case. Following that case, a root-cause analysis was undertaken and an algorithm to solve the problem was developed (3). A similar incident involving the failure of a component of CPB was reported by Ottens et al. Their case involves disconnection of the Cobe SMARxT tubing (Sorin Group) from the venous outlet of the Terumo Capiox SX25RX Oxygenator (Terumo Cardiovascular Systems Corporation, Ann Arbor, MI) (4). Both cases illustrate that although rare, failure of CPB components do occur and if not managed adequately, can have lethal consequence to the patients.

In our case, a failure of the membrane oxygenator was detected intra-operatively during CPB. In our institution, with awareness of previous incidents, an algorithm was available (Figure 2). The algorithm was adhered to strictly in this case. In addition, our perfusion staff perform regular simulation drills. With the cohesive effort from every member of the team, the membrane oxygenator was successfully replaced in just 2 minutes and as a consequence, the patient suffered no complication. The replaced oxygenator was sent for analysis to delineate the problem. Response from the manufacturer listed potential causes of a rise in the transmembrane pressure of the oxygenator included 1) platelet accumulation in the fibers of the oxygenator membrane and 2) “water logging” of the oxygenator membrane. However, these could not be conclusively proven due to the decontamination process of the manufacturing company prior to analysis of failure.

Groom et al. proposed replacement of the failed oxygenator by inserting a second oxygenator in parallel within the cardiopulmonary bypass circuit obviating the need to stop CPB (5). However, as we are not familiar with this technique, it was not used in this case. In our center, the perfusion staff perform simulation drills on a weekly basis for management of emergency situations, which includes oxygenator replacement. We feel that this practice has enabled the safe and smooth replacement of the oxygenator in this case. This is supported by Darling and Searles, who suggested that written protocols with simulation

**Table 1.** Arterial blood gas analysis at commencement of CPB, prior to membrane oxygenator replacement and post replacement of failed oxygenator.

<table>
<thead>
<tr>
<th>Blood Gas Analysis</th>
<th>pH</th>
<th>pCO2</th>
<th>pO2</th>
<th>BE</th>
<th>Sat</th>
<th>K+</th>
<th>Lactate</th>
<th>Glucose</th>
<th>Hb</th>
<th>HCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commencement of CPB</td>
<td>7.31</td>
<td>5.66</td>
<td>30.7</td>
<td>–4.6</td>
<td>99.4</td>
<td>3.8</td>
<td>2</td>
<td>10.6</td>
<td>6.9</td>
<td>21.6</td>
</tr>
<tr>
<td>2 mins post commencement of CPB</td>
<td>7.22</td>
<td>7.59</td>
<td>39.9</td>
<td>–3.9</td>
<td>99.4</td>
<td>3.9</td>
<td>2.1</td>
<td>11</td>
<td>7.5</td>
<td>23.5</td>
</tr>
<tr>
<td>15 mins post commencement of CPB</td>
<td>7.21</td>
<td>7.65</td>
<td>44.5</td>
<td>–4.5</td>
<td>99.5</td>
<td>3.8</td>
<td>2.1</td>
<td>11</td>
<td>7.5</td>
<td>23.6</td>
</tr>
<tr>
<td>30 mins post commencement of CPB</td>
<td>7.19</td>
<td>8.35</td>
<td>47</td>
<td>–3.7</td>
<td>99.4</td>
<td>3.9</td>
<td>2</td>
<td>10.8</td>
<td>7.5</td>
<td>23.4</td>
</tr>
<tr>
<td>Prior to oxygenator replacement</td>
<td>7.13</td>
<td>8.75</td>
<td>60</td>
<td>–7</td>
<td>99.4</td>
<td>4.5</td>
<td>1.8</td>
<td>8.9</td>
<td>6</td>
<td>18.8</td>
</tr>
<tr>
<td>3 mins post oxygenator replacement</td>
<td>7.15</td>
<td>8.35</td>
<td>9</td>
<td>–6.8</td>
<td>87</td>
<td>4.9</td>
<td>2.1</td>
<td>8.9</td>
<td>7</td>
<td>22</td>
</tr>
<tr>
<td>18 mins post oxygenator replacement</td>
<td>7.3</td>
<td>5.1</td>
<td>37.9</td>
<td>–6.8</td>
<td>99.6</td>
<td>5.5</td>
<td>2.2</td>
<td>9</td>
<td>6.7</td>
<td>20.8</td>
</tr>
<tr>
<td>60 mins post oxygenator replacement</td>
<td>7.4</td>
<td>4.34</td>
<td>35.1</td>
<td>–4.2</td>
<td>99.8</td>
<td>6</td>
<td>2.1</td>
<td>8.2</td>
<td>7.8</td>
<td>24.4</td>
</tr>
</tbody>
</table>

PO2, partial pressure of oxygen; Sat, oxygen saturation; BE, base excess; K+, potassium; Hb, hemoglobin; HCT, hematocrit.

**Figure 1.** Failed Sorin PrimO2X membrane oxygenator.
practice are important in improving efficiency in emergency situations (6). Therefore, we propose that all cardiac surgery departments should be aware of these incidents and an algorithm should be put in place and adhered to with regular simulation drills to improve efficiency if such a situation were to occur.

REFERENCES


Figure 2. Protocol for oxygenator changeover.