Effect of Different Pump Heads for CPB on Early Cognitive Outcome after Coronary Artery Bypass Surgery

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Objectives: Reduction of cognitive function is a possible side effect after coronary artery surgery using cardiopulmonary bypass (CPB). We investigated the effect of roller versus centrifugal pumps for CPB on cognitive performance in patients undergoing coronary artery bypass grafting (CABG).

Methods: 50 consecutive CABG patients operated with centrifugal pump were compared to 50 roller pump patients matched for age and duration of CPB. Six neuropsychological subtests from the Syndrom Kurz Test and the Alzheimer’s Disease Assessment Scale were performed preoperatively and on the third postoperative day in a double blind fashion. To assess the overall cognitive function and the degree of cognitive decline across all tests after surgery we combined the six test-scores by principal component analysis.

Results: Patients with a mean age of 63.9 ± 8.4 years received a mean of 3.0 ± 0.9 bypasses within an average of 80.6 ± 20.7 mins on CPB. These parameters as well as the preoperative combined neurocognitive score were not significantly different between the groups. After the operation there was a significant deterioration of the combined neuropsychological score in both groups (centrifugal: preop 0.41 ± 2.49 vs. postop −2.86 ± 2.70, p < 0.0005 and roller: preop −0.41 ± 2.35 vs. postop −2.73 ± 3.16, p < 0.0005). However, the patients operated with a centrifugal pump had a significantly greater decline of overall cognitive function compared to the roller pump patients (3.3 ± 1.7 vs. 2.3 ± 2.7, p = 0.04).

Conclusion: Roller pumps have a less cerebro-damaging effect than centrifugal pumps since they lead to a smaller postoperative decline of neuropsychological abilities in coronary bypass patients.

Keywords: coronary artery bypass surgery, cardiopulmonary bypass, cognition disorders

Introduction

CABG to treat coronary artery disease is the most common operation in the cardiac surgical field. It is routinely performed using CPB to be able to work on the arrested heart. Although CABG is a relatively safe and effective procedure, relevant cognitive impairments can be observed in a significant amount of patients after the operation.1) Different perioperative factors are accused to cause the cognitive decline after CABG like microembolism, hypoperfusion or drugs.2,3) It is known that deleterious microemboli can also originate from the
pump heads used for CPB which are either roller or centrifugal type and work in different ways. Roller pumps displace blood by compressing tubing with a roller whereas centrifugal pumps use an impeller to propel the blood forward. It had been shown that centrifugal pumps lead to lower inflammatory response, less trauma of blood as well as fewer microemboli delivered to the patient. Therefore, it was assumed that they have also less negative impact on postoperative cognitive performance of the patients. However, postoperative differences of neuropsychological abilities were not found so far. Since there exist very few studies dealing with that issue without a final conclusion we were encouraged to contribute to this investigation. The resulting purpose of this study is to evaluate the effect of different pump heads for CPB on early cognitive outcome after coronary artery bypass surgery.

Methods

Study Design/Protocol

Patients who had an indication for an elective isolated primary CABG according to the ACC/AHA guidelines were included if they gave their written informed consent. Patients with any known neuropsychological diseases (e.g. dementia) were excluded. Patients were operated with a centrifugal pump before the 1st October 2009. Afterwards patients were operated with a roller head pump. This was due to a complete change of pump heads in our department at that time. 50 consecutive centrifugal pump patients were compared to 50 roller pump patients matched for age and duration of CPB. The Study was conducted in a double blinded fashion. Cognitive function was evaluated the day before surgery and on the third postoperative day.

Neuropsychological assessment

Patients were examined with a neuropsychological tests battery for memory and attention lasting approximately 20 mins and consisting of the following 6 subtests of SKT (Syndrome Kurz Test) and ADAS (Alzheimer’s Disease Assessment Scale). Assessment took place at patient’s bedside without any distraction.

$S_1$ immediate pictured object recall
—patient is asked to remember as many as possible of 12 pictures shown 20 secs.

$S_2$ immediate word recall
—patient is asked to remember as many as possible of 10 words each shown 2 secs.

$S_3$ attention
—patient is asked to perform a certain counting task as quick as possible.

$S_4$ letter interference
—patient is asked to perform a certain reading task as quick as possible.

$S_5$ delayed pictured object recall
—patient is asked to remember as many as possible of 12 previously shown pictures after a delay of 10 mins.

$S_6$ delayed picture recognition
—patient is asked to recognize as many as possible of 12 previously viewed pictures after a delay of 15 mins.

Except for test $S_3$ and $S_4$ lower scores mean poorer performance. The tests were performed in two parallel forms in order to minimize practice effects at the postoperative retest. For examples of test material see Fig. 1.

Fig. 1 Examples of test material for immediate object recall (A), attention (B) and letter interference (C) assessment.
Coronary artery bypass grafting and postoperative care

Patients were premedicated with benzodiazepines. General anaesthesia was conducted using propofol or isoflurane, opiates and muscle relaxans. Median sternotomy and full heparinization was performed and the bypass grafts were harvested. Whenever possible a complete revascularization of the patient was performed. In patients younger than 60 years old we tried to use mainly arterial grafts like LIMA, RIMA and radial artery. In patients older than 60 years the LIMA was used for the LAD and saphenous vein grafts for the other coronaries. LIMA, RIMA and radial artery were used in 94%, 12% and 2% respectively. The pericardium was opened, the ascending aorta and right atrium were cannulated and normothermic cardiopulmonary bypass was started. Either a heart lung machine with roller pumps (System1, Terumo®) or a system with centrifugal pumps (Rotaflow, Maquet®) was used. Pre-bypass filter was used in any case. The aorta was cross clamped, cardioplegic solution infused and the distal anastomoses performed on the arrested heart. After release of the aortic cross clamp the heart usually started beating spontaneously and the proximal anastomoses were sutured. Ventilation was started and the patient was weaned from CPB. The chest was closed and the patient transferred to the ICU. We did not perform any patency rate studies in our patients because this was done extensively by other groups.8) Coronary angiography was only performed if the patient presented with signs of ischemia. Postoperative anemia was generally managed with prescription of oral ferrous gluconate for seven days or longer depending on the ferritin level. Blood transfusions are performed if the hematocrit is less than 0.25 particularly in patients older than 80 years and/or those with an ejection fraction lower than 35%.

Statistics

Statistical analysis was done using SPSS® 14.01 (SPSS Inc., Chicago, USA). The level of significance was α = 0.05.

To assess the overall cognitive function and the degree of cognitive decline across all tests after surgery we combined the six test-scores by principal component analysis.

\[ S_{i, \text{pre}} = 0.29 \times z_{1, \text{pre}} + 0.24 \times z_{2, \text{pre}} - 0.22 \times z_{3, \text{pre}} - 0.25 \times z_{4, \text{pre}} + 0.26 \times z_{5, \text{pre}} + 0.22 \times z_{6, \text{pre}} \]

is the first principal component of the standardized scores before operation (baseline), i.e.

\[ z_{i, \text{pre}} = \frac{S_{i, \text{pre}} - \mu(S_{i, \text{pre}})}{\sigma(S_{i, \text{pre}})} \quad i = 1, \ldots, 6. \]

with \( \mu(S_{i, \text{pre}}) \) and \( \sigma(S_{i, \text{pre}}) \) the mean and standard deviation of \( S_{i, \text{pre}} \). The same transformation was applied to the scores \( S_{i, \text{post}}, \ldots, S_{6, \text{post}} \) after operation.

\[ S_{\text{post}} = 0.29 \times z_{1, \text{post}} + 0.24 \times z_{2, \text{post}} - 0.22 \times z_{3, \text{post}} - 0.25 \times z_{4, \text{post}} + 0.26 \times z_{5, \text{post}} + 0.22 \times z_{6, \text{post}} \]

with

\[ z_{i, \text{post}} = \frac{S_{i, \text{post}} - \mu(S_{i, \text{pre}})}{\sigma(S_{i, \text{pre}})} \quad i = 1, \ldots, 6. \]

Note, the mean \( \mu(S_{i, \text{pre}}) \) and standard deviation \( \sigma(S_{i, \text{pre}}) \) of the pre-operative sores are used in the transformation formula for the \( z_{i, \text{post}} \).

Changes in the scores (preop—postop) were compared by Mann-Whitney-U test and comparisons of preoperative with corresponding postoperative scores within the treatment groups were conducted by Wilcoxon tests for paired samples.

Comparison of age, CPB time and number of bypasses between the groups was done also by Mann-Whitney-U test.

Results

100 patients (94 male) were included into the study with a mean age of 63.9 ± 8.4 years. There was a mean time on CPB of 80.6 ± 20.7 mins. Patients of roller and centrifugal pump group were comparable in terms of age, number of bypass grafts and duration of CPB indicating a homogenous study sample (see Table 1).

None of the patients had signs of postoperative cardiac ischemia. Mean pre- and postoperative hemoglobin level were 14.0 ± 1.4 mg/dl and 10.8 ± 1.4 mg/dl, respectively.

Preoperative overall cognitive function was similar in both groups (roller: \(-0.41 ± 2.35\) vs. centrifugal: \(0.41 ± 2.49, \ p = 0.09\)). Comparison of postoperative testing with preoperative testing revealed a significant decline of overall test results in both groups (roller: preop \(-0.41 ± 2.35\) vs. postop \(-2.73 ± 3.16, \ p < 0.0005\) and centrifugal: preop \(0.41 ± 2.49\) vs. postop \(-2.86 ± 2.70, \ p < 0.0005\)). Overall cognitive results reflected results of the subtests. Patients of both treatment groups showed significantly worse postoperative results compared to the baseline in all subtests, except results of
Table 1  Demographic and operative data

<table>
<thead>
<tr>
<th>Variable</th>
<th>All patients</th>
<th>Centrifugal group</th>
<th>Roller group</th>
<th>p value roller vs centrifugal</th>
</tr>
</thead>
<tbody>
<tr>
<td># patients</td>
<td>100</td>
<td>50</td>
<td>50</td>
<td>—</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>63.9, 46–80, 8.4</td>
<td>63.8, 46–76, 7.8</td>
<td>64.0, 47–80, 9.2</td>
<td>0.89</td>
</tr>
<tr>
<td># Bypasses</td>
<td>3.0, 1–6, 0.9</td>
<td>3.2, 1–6, 0.9</td>
<td>2.9, 1–4, 0.9</td>
<td>0.23</td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>80.6, 32–120, 20.7</td>
<td>80.8, 36–120, 21.0</td>
<td>80.5, 32–120, 20, 6</td>
<td>0.95</td>
</tr>
</tbody>
</table>

CPB: cardiopulmonary bypass

Table 2  Comparison of cognitive test results (C = Centrifugal, R = Roller, ns = non significant)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Preop Mean ± SD</th>
<th>Postop Mean ± SD</th>
<th>p value Preop vs postop</th>
<th>p value Preop-Postop: C vs R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate pictured object recall</td>
<td>C</td>
<td>5.7 ± 1.5</td>
<td>4.5 ± 1.3</td>
<td>&lt;0.0005</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>6.0 ± 1.3</td>
<td>5.0 ± 1.8</td>
<td>&lt;0.0005</td>
<td></td>
</tr>
<tr>
<td>Delayed pictured object recall</td>
<td>C</td>
<td>5.2 ± 2.1</td>
<td>3.8 ± 1.8</td>
<td>&lt;0.0005</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>3.8 ± 1.7</td>
<td>3.1 ± 2.2</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Delayed picture recognition</td>
<td>C</td>
<td>10.1 ± 1.6</td>
<td>8.5 ± 1.8</td>
<td>&lt;0.0005</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>8.9 ± 2.2</td>
<td>7.5 ± 2.5</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Immediate word recall</td>
<td>C</td>
<td>5.2 ± 1.6</td>
<td>4.0 ± 1.3</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>4.8 ± 1.3</td>
<td>4.9 ± 1.4</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Letter interference</td>
<td>C</td>
<td>26.2 ± 6.2</td>
<td>31.5 ± 10.3</td>
<td>&lt;0.0005</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>28.1 ± 7.9</td>
<td>33.8 ± 11.6</td>
<td>&lt;0.0005</td>
<td></td>
</tr>
<tr>
<td>Attention</td>
<td>C</td>
<td>20.1 ± 3.9</td>
<td>27.6 ± 7.2</td>
<td>&lt;0.0005</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>16.8 ± 6.3</td>
<td>24.0 ± 8.4</td>
<td>&lt;0.0005</td>
<td></td>
</tr>
<tr>
<td>Overall cognitive function</td>
<td>C</td>
<td>0.41 ± 2.5</td>
<td>−2.86 ± 2.7</td>
<td>&lt;0.0005</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>−0.41 ± 2.4</td>
<td>−2.74 ± 3.2</td>
<td>&lt;0.0005</td>
<td></td>
</tr>
</tbody>
</table>

roller patients in the immediate word recall test. Analysis of the cognitive change preop—postop) revealed that the decline of overall cognitive function was significantly greater in the centrifugal group compared to the roller group (centrifugal: 3.3 ± 1.7 vs. roller: 2.3 ± 2.7, p = 0.04), see Table 2 and Fig. 2. This was based on a greater decline of the cognitive results in three of six subtests of the centrifugal pump patients.

Besides the cognitive declines there were no complications due to micro- or macroembolisation.

Discussion

Cognitive impairments were frequently detected after coronary bypass surgery with CPB and are of clinical relevance. Genesis of neuropsychological deficits is most likely multifactorial. Hypoperfusion states during the operation particularly in the presence of a cerebral vascular disease, toxic influence of narcotics and microemboli from either atherosclerotic debris or the extracorporeal circuit including the pump heads are involved in the cognitive changes.

We evaluated the cognitive impact of roller and centrifugal pumps. Patients operated with a centrifugal pump had a significant greater decline of overall cognitive function compared to the roller pump patients. To our knowledge this is the first study demonstrating a cognitive disadvantage of patient operated with centrifugal pumps. Very few studies have investigated association between cognitive change and the type of pump head used for CPB in coronary surgery, indeed. However, these studies did not show neuropsychological differences although this was expected due to less blood trauma and fewer microemboli caused by centrifugal pumps. To our mind, impact on cognitive abilities of injury to cellular components and microbubble transmission due to the high pressure and high shear forces caused by roller pumps might be overestimated. Patients operated with centrifugal pumps did not show a greater preservation of their neurocognitive function in fact it was even worse.

Thus, our results advocate rather to use a roller pump at least from the cognitive standpoint. There is no doubt that complete avoidance of CPB would yield to less cognitive decline than with any pump type. However, preservation of cognitive function is as important as achieving the main goal of coronary surgery namely complete and accurate revascularization which
is definitely more difficult to achieve with off-pump bypass surgery.

Beside the efforts to eliminate the causative mechanisms of cognitive decline, attempts were also undertaken to directly protect the brain. Different potentially cerebroprotective substances, like piracetam, which proved to be effective in CAGB patients, have been evaluated to lower the cognitive changes associated with CPB. Patients that received a single dose of 12 g Piracetam i.v. at the beginning of the operation performed significantly better early after the operation and had less decline of overall cognitive function compared to placebo patients.

Neuropsychological test selection in our study was based on tests procedures that require a minimum of motor activity considering the early postoperative patient situation. A brief battery of neuropsychological tests for verbal and non-verbal short term memory and attention were tested. Other cognitive functions may also be affected by the surgery but because of the limited cooperation of patients, a selection of psychometric instruments had to be made. Most of them were chosen from the repeatable test battery SKT. It is a standardized screening instrument designed to assess cognitive function in a brief administration. Evaluation of the results of neuropsychological assessment was rather performed for each group than for every single patient. It was not intended to classify the neuropsychological abilities of a specific patient but to evaluate the differences between the pump groups before and after the operation.

Further work is necessary to identify and reduce factors that negatively influence cognitive function in patients undergoing coronary artery bypass surgery because they reduce patient’s quality of life and complicate their rehabilitation. Moreover they increase in-hospital mortality and length of stay and last but not least the use of resources. A limitation of the study is, that there was no randomization of the patients to the pump groups because both types of pumps were not available at our institution at the same time. However, patients of both groups were well matched concerning age and duration of CPB which had been described to be associated with the amount of cerebral microembolism. Furthermore, MRI studies of the brain would have been interesting but were not available since the patients did not show clinical abnormalities associated with macro- or relevant microembolism. Particularly there were no alarming neurologic symptoms like focal deficits, seizures or somnolence.
In summary, roller pumps have a less cerebro-damaging effect than centrifugal pumps since they reduce an early postoperative decline of neuropsychological abilities in coronary bypass patients.

Disclosure Statement

The authors have nothing to disclose and there is no conflict of interest.

References