A Healthy Volunteer Study: Does Trendelenburg position lead to cognitive decline?

Abstract

Background

Postoperative cognitive decline (POCD) is defined as a new cognitive impairment arising after surgical intervention. Aspects of cognitive function can be assessed using various validated cognitive function tests including: N back; Stroop; and Lexical Decision Making Task (LDT). There is some concern that prolonged Trendelenburg positioning during laparoscopic colorectal surgery may cause POCD.

Objective

To assess the effect of the time spent in Trendelenburg position on cognitive function.

Methods

Volunteers were placed in Trendelenburg for 3 hours, then supine for 30 minutes. Validated cognitive function tests including: 1,2, 3 back; Stroop; and LDT were performed at baseline and every 30 minutes after Trendelenburg position. Cognitive decline was defined as per the ISPOCD trial [1]: a decrease in accuracy from the volunteers' baseline or an increase in response time (RT) from the volunteers' baseline by > 2 control group standard deviations (SD).

Results

Fifteen healthy volunteers were recruited (8 male, 7 female), average age of 69 years (range:57-81) and average BMI of 27.7 kg/m² (range:20.9-33).

Accuracy remained within 2 SDs at all time-points. An increase in RT did occur with 20% showing cognitive decline after 30 minutes in Trendelenburg position, 26.7%
after 1 hour, 33.3% after 90 minutes, 26.7% after 120 and 150 minutes; and 40% after 180 minutes. When moved supine, 33.3% had cognitive decline.

Discussion

The results of this study indicate that Trendelenburg positioning appears to lead to cognitive decline. This may have implications for patients undergoing prolonged Trendelenburg positioning in laparoscopic colorectal surgery.

Keywords:
POCD; Trendelenburg; Cognitive function; Laparoscopic

Introduction

Impairment of cognitive function following surgery has been recognised since the 1950’s. Postoperative cognitive decline (POCD) is defined as a new cognitive impairment arising after surgical intervention [2]. It is a subtle disorder of thought processes, which may influence isolated domains of cognition such as verbal memory, visual memory, language comprehension, visuospatial abstraction, attention, or concentration [3]. POCD can lead to increased hospital stay, higher readmission rates, impairment of daily functioning, delayed return to work/normal level of functioning and dependency on government economic assistance post discharge from hospital [4]. It can affect patients at any age, but was shown to have a longer and more significant effect on daily life activities and return to work in patients over 60 years.

Trendelenburg positioning is commonly used during laparoscopic colorectal surgery to allow the use of gravity to move the small bowel out of the pelvis and provide the surgeon with adequate views. The degree of tilt and time spent in these positions varies depending on the type of resection and complexity of the case. The
The gravitational effect of the Trendelenburg position is thought to divert blood away from lower extremities and increase central blood volume [5]. This increases cerebral blood flow and intracranial pressure (ICP) by impairing venous outflow from the brain, increasing hydrostatic pressure within the cerebral vasculature pushing fluid into the extracellular spaces. After being in steep Trendelenburg for a prolonged period, significant cerebral perivascular oedema can develop. All of these can cause impaired cerebral perfusion and cerebral oedema [6]. If significant cerebral perivascular oedema develops, the effective cerebral perfusion may significantly reduce [7], resulting in impaired tissue oxygenation and therefore leading to cognitive decline [8].

The N-back task is used as a measure of working memory and executive function [9]. It is favoured as the ability to change the value of “N” gives researchers a reliable way of altering the processing load of the task [10]. The Stroop test provides a paradigm case of attention and inhibition. The Stroop effect is recognised as the inclination to say the word presented, rather than the colour that it appears in. A delay in response is usually seen when the colour of the word does not match the meaning of the word (an “incongruent stimulus”) [11-13]. Lexical decision task primarily tests the language aspect of cognitive function. Executive functions (decision-making) are also tested in this task, as a quick decision must be made as to whether the letters form a word or not [14].

The aim of this study was to assess the effect of the amount of time spent in Trendelenburg position on cognitive function.
Methods

This study was reviewed and approval given by the University of Nottingham Research Ethics Committee (Reference No: N14082014 SoM GI Surgery NDDC).

Recruitment

Healthy volunteers over 18 years old were recruited. Volunteers with pre-existing cognitive impairment, smokers, inability to read or understand English, visual impairment or refusal to give written informed consent were excluded from our study.

After practicing each test three times (to allow for the learning effect of repeated tests), a baseline performance for each cognitive function tasks were recorded whilst sitting for: 1 back; 2 back; 3 back; Stroop; LDT.

The volunteers were then placed in the Trendelenburg position at 17° head-down for 3 hours, then moved to supine position for 1 hour and then sat up. The above tests were then repeated after: 30 minutes; 1 hour; 1.5 hours; 2 hours; 2.5 hours; 3 hours (volunteer moved to supine position after 3 hours, so these tests were performed immediately when moved to supine); 3.5 hours; 4 hours (after 4 hours, the volunteer was sat up in a chair and the tests were performed immediately after sitting up.) Between 90 minutes and 2 hours, 5 of the volunteers had a ‘toilet break’. The toilet breaks ranged between 2.5 minutes and 4.8 minutes including walking to and from the toilet. This was an unavoidable break as our volunteers were awake.

Control Data

To allow for the continued learning effect that may mask the cognitive decline, a control group was recruited to provide control data for analysis. Five volunteers repeated each test 4 times. Each test was analysed individually and the mean and
standard deviation was calculated for both a change in accuracy and a change in response time (RT) between the 3rd and 4th attempt of the tests. The mean change was taken to represent the learning effect for the tests which is known to occur when the same tasks are repeated multiple times.

**Statistical Analysis**

**Power**

A Statistical power analysis was performed for sample size estimation, based on data from Brookes et al who compared the effect of increased task difficulty on MEG activity. They detected a mean accuracy for 1-back task as 98% ± 2 (SD) and 2-back test as 91% ± 8 (SD). With an alpha=0.05 and power=0.80, the projected sample size needed with this effect size (STATA 14.0) was n=10 [15]. We therefore chose to recruit 15 volunteers to our study.

A repeated measures analysis was performed to compare the change in accuracy and RT at each time point. For each volunteer, the accuracy and RT at each time point was subtracted from their baseline. A repeated measures test was then performed using STATA.

To assess the percentage of volunteers who suffered cognitive decline the ISPOCD study definition was used. [1] The baseline was subtracted from the results at each time point, and then the learning effect was also subtracted from this change in ‘test score’. This result was then divided by the standard deviation of the control group to give a Z score. A large positive Z score (z>1.96) showed a deterioration in cognitive function from baseline for accuracy, and a large negative Z (z< -1.96) score for RT [16].
Results

Fifteen healthy volunteers completed the study. Of the 15 volunteers, 8 were male, 7 were female. They had an average age of 69 years (± 6.98) and average BMI of 27.7 kg/m² (± 3.4).

Table 1 and Table 2 shows the results of repeated measures analysis of change in accuracy and response time from volunteers own baseline respectively.

<table>
<thead>
<tr>
<th>Time Point</th>
<th>Event</th>
<th>Accuracy Mean change from baseline (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>30 minutes after Trendelenburg Position</td>
<td>-0.04 (-0.072, 0.001)</td>
<td>0.06</td>
</tr>
<tr>
<td>3</td>
<td>60 minutes after Trendelenburg position</td>
<td>-0.01 (-0.05, 0.03)</td>
<td>0.66</td>
</tr>
<tr>
<td>4</td>
<td>90 minutes after Trendelenburg position</td>
<td>0.01 (-0.03, 0.05)</td>
<td>0.67</td>
</tr>
<tr>
<td>5</td>
<td>120 minutes after Trendelenburg position</td>
<td>0.02 (-0.02, 0.05)</td>
<td>0.44</td>
</tr>
<tr>
<td>6</td>
<td>150 minutes after Trendelenburg position</td>
<td>0.002 (-0.35, 0.04)</td>
<td>0.91</td>
</tr>
<tr>
<td>7</td>
<td>Supine (after 180 minutes in Trendelenburg)</td>
<td>0.02 (-0.01, 0.06)</td>
<td>0.20</td>
</tr>
<tr>
<td>8</td>
<td>30 minutes after Supine position</td>
<td>0.01 (-0.03, 0.04)</td>
<td>0.82</td>
</tr>
<tr>
<td>9</td>
<td>Sitting up (60 minutes after Supine position)</td>
<td>0.02 (-0.02, 0.06)</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Table 1 Repeated measures analysis of change in accuracy from volunteers own baseline for each time point
The percentage of volunteers with cognitive decline from their baseline was analysed (Table 3).

<table>
<thead>
<tr>
<th>Time Point</th>
<th>Event</th>
<th>Accuracy Mean change from baseline (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>30 minutes after Trendelenburg Position</td>
<td>-0.04 (-0.11, 0.04)</td>
<td>0.34</td>
</tr>
<tr>
<td>3</td>
<td>60 minutes after Trendelenburg position</td>
<td>-0.08 (-0.16, 0.01)</td>
<td>0.03</td>
</tr>
<tr>
<td>4</td>
<td>90 minutes after Trendelenburg position</td>
<td>-0.11 (-0.18, -0.03)</td>
<td>0.004</td>
</tr>
<tr>
<td>5</td>
<td>120 minutes after Trendelenburg position</td>
<td>-0.15 (-0.22, -0.07)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6</td>
<td>150 minutes after Trendelenburg position</td>
<td>-0.14 (-0.22, -0.07)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>7</td>
<td>Supine (after 180 minutes in Trendelenburg)</td>
<td>-0.19 (-0.26, -0.11)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>8</td>
<td>30 minutes after Supine position</td>
<td>-0.15 (-0.22, -0.07)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>9</td>
<td>Sitting up (60 minutes after Supine position)</td>
<td>-0.16 (-0.23, -0.08)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 2 Repeated measures analysis of change in response time from baseline for each time point

The percentage of volunteers with cognitive decline from their baseline was analysed (Table 3).
<table>
<thead>
<tr>
<th></th>
<th>function</th>
<th>cognitive decline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80.00</td>
<td>20.00</td>
</tr>
<tr>
<td>2</td>
<td>73.33</td>
<td>26.67</td>
</tr>
<tr>
<td>3</td>
<td>66.67</td>
<td>33.33</td>
</tr>
<tr>
<td>4</td>
<td>73.33</td>
<td>26.67</td>
</tr>
<tr>
<td>5</td>
<td>73.33</td>
<td>26.67</td>
</tr>
<tr>
<td>6</td>
<td>60.00</td>
<td>40.00</td>
</tr>
<tr>
<td>7</td>
<td>66.67</td>
<td>33.33</td>
</tr>
<tr>
<td>8</td>
<td>60.00</td>
<td>40.00</td>
</tr>
</tbody>
</table>

Table 3 Average RT of tests at each time point with the percentage of volunteers with cognitive decline from their baseline. 1-Trendelenburg 30 minutes, 2-Trendelenburg 60 minutes, 3- Trendelenburg 90 minutes, 4- Trendelenburg 120 minutes, 5- Trendelenburg 150 minutes, 6- Trendelenburg 180 minutes/supine 0 minutes, 7- Supine 30 minutes, 8- Supine 60 minutes/volunteer sat-up

Discussion

Our study showed a decline in cognitive function following Trendelenburg positioning. The overall percentage of volunteers with cognitive decline increased to...
40% after 3 hours in the Trendelenburg position. After 1.5 hours 33.3% had cognitive decline, but this reduced to 26.7% after 2 hours. This could be due to adaptation to being placed in the Trendelenburg position as per the Monroe-Kellie doctrine, or possibly due to 5 of the 15 volunteers requiring a toilet break between 90 minutes and 2 hours into the test [17].

Once the patient was sat up (after 3 hours in the Trendelenburg position and 1 hour supine), the initial tests revealed a slight increase again in those with overall cognitive decline from 33.3% to 40%. When sitting from a supine position, there are many physiological changes that initially occur. Deegan et al recruited 19 healthy volunteers and induced transient hypotension whilst in both the seated and supine position and measured mean arterial pressure, cerebral blood flow in the middle and anterior cerebral artery along with cerebral autoregulation response. They found auto regulatory responses were worse in the seated position in both the anterior and middle cerebral artery which was thought to be due to the hydrostatic gradient that occurs whilst seated [18]. Previous studies have shown that cerebral autoregulation is dependent on vascular tone [19]. Deegan et al found a drop in cerebral perfusion pressure lead to dilatation of cerebral vessels which resulted in reduced cerebral vascular resistance. They also looked at the theory of reduced cerebral perfusion pressure resulting from a shift in the auto regulatory curve to the right. However, the subjects included in their study did respond with an increased heart rate suggesting a sympathetic response which should result in vasoconstriction and therefore an increase in cerebral vascular resistance [18]. This could explain the increase in percentage of volunteers with cognitive decline that occurred at time point 8.
This break was taken between time points 3 and 4 and lasted a maximum of 5 minutes. The volunteers then returned to the Trendelenburg position. This break could explain the reduction in percentage of volunteers with cognitive decline at time point 4. The resulting reduction in cognitive decline that may have occurred following a short period in the upright position compared to the worsened cognitive decline that occurred when in the sitting position, this further supports the reduced cerebral perfusion pressure that has been shown to occur when in the seated position versus the standing position. Patients undergoing laparoscopic left-sided resections are often placed in either a modified lithotomy position (with the legs slightly flexed) or Lloyd-Davis. Further studies to re-asses the response of a standing/head-up tilt on recovery of cognitive function would be of clinical benefit.

There were limitations to this study which included a bathroom break that was taken that may have affected the results achieved at time point 4. Test fatigue could also be a contributing factor with repetitive tests being carried out in such a short time period. A repeat set of tests 24 hours after the end of the study would possibly have been beneficial for assessing the clinical impact. Although all volunteers remained

A further limitation is due to the lack of a clear definition for defining POCD. ISPOCD is the largest study in this area so far, but treats POCD as a binary definition. The clinical implications and impact in daily life of these definitions need to be further evaluated and defined along with standard tests that should be used. The high percentage of cognitive decline could be due to the sensitivity and number of the cognitive tests that were used in our study.
Conclusion

The results of our study do indicate that Trendelenburg positioning does lead to cognitive decline. Our results also suggest that when in a clinical setting, simply reducing the tilt of the table when the patient is in the modified lithotomy of Lloyd-Davis position may not be the beneficial as this most likely would mimic the physiology of sitting as this could further impair cognitive function due to reduced cerebral vascular resistance that occurs [18].

Further studies to assess the effect of a ‘break from Trendelenburg’ whilst in the modified lithotomy or Lloyd-Davis position versus supine would also be clinically relevant.

Conflicts of Interest

None

Abbreviations

LDT: Lexical Decision Making Task
POCD: Post-operative cognitive decline
RT: response time

References