Pretraining of basic skills on a virtual reality vitreoretinal simulator: a waste of time

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**Abstract (250 of 250 words allowed)**

**Purpose:** To investigate whether pretraining of basic skills in virtual vitreoretinal surgery affected the performance-curve when proceeding to procedure-specific modules.

**Methods:** This study was a prospective, randomised, controlled, two-centre study. Medical students were randomised into two groups: Group 1 pretrained basic psycho-motor skills (Navigation Training level 2 and Bimanual Training level 3), until they reached their performance-curve plateau. Hereafter, both groups trained on the procedure-specific modules (Posterior Hyaloid level 3 and ILM Peeling level 3) until they reached their performance-curve plateau. Plateau was defined as three consecutive sessions with the same score with an acceptable variation. The primary outcome was time used to reach performance-curve plateau in the procedure-specific modules.

**Results:** A total of 68 medical students were included, and equally randomised into two groups. The participants in Group 1 used a median time of 88 minutes to reach plateau in the basic skills modules, but did not differ from group 2 in time to reach plateau on the procedure-specific modules (183 minutes versus 210 minutes, \( p = 0.40 \)), or in the amplitude of plateau. Group 1 and 2 differed significantly in the starting score of ILM peeling level 3 (0 (0-0) versus 3.5 (0-75), \( p = 0.03 \)).

**Conclusion:** We were not able to show positive skill transfer from basic skills training to the procedure-
specific modules. Neither in time, starting score, or amplitude of plateau. Thus, we recommend that aspiring vitreoretinal surgeons proceed directly to simulation-based training of procedures in stead of spending valuable training time on basic skills training.

Keywords
Simulation-based training; basic skills training; transfer of skill; procedural training; vitreoretinal surgery; assessment; virtual reality.

Introduction
Simulation training has gained impact as an evidence-based learning tool to obtain better skills in complicated surgical procedures. In ophthalmology, the EyeSi Surgical Simulator (VRmagic GmbH, Manheim, Germany) is one of the most researched simulators in the literature (Thomsen et al. 2015; Rasmussen et al. 2019; Lee et al. 2020), on which it is possible to train both cataract and vitreoretinal surgery. In cataract surgery, a training program has been established, which has improved operating room performance with decreasing complications among novice surgeons (McCannel et al. 2013; Pokroy et al. 2013; Thomsen et al. 2015; Thomsen et al. 2017). Also, a vitreoretinal training program consisting of two basic skills modules and two procedure-specific modules have previously been compiled (Vergmann et al. 2017). The principle of pretraining basic psycho-motor skills on abstract simulation modules has also been applied in cataract surgery training, in which the basic skills modules must be mastered before moving on to the procedure-specific modules (McCannel et al. 2013). By this, it is assumed that the trainee acquires a set of skills, which makes the learning of procedure-specific modules more efficient. Transfer of skills is defined as the influence of previous experiences on learning a new skill or performing a skill in a new context. The influence can facilitate, inhibit, or have no effect on new learning; hereof a positive, negative, or neutral transfer can occur (Magill & Anderson 2014). However, a previous study investigating inter-procedural transfer of skills between cataract and vitreoretinal modules, has established doubt whether inter-procedural transfer of skill takes place on the EyeSi Surgical Simulator (Thomsen et al. 2017).
Consequently, by not knowing whether a positive transfer of skill is actually taking place, future vitreoretinal surgeons may risk spending time and resources on training elements with no beneficial effect.

Thus, the purpose of this study was to investigate whether pretraining basic skills with abstract modules on the EyeSi Surgical Simulator had a positive effect on the time to reach plateau on the performance-curve in the procedure-specific modules in virtual vitreoretinal surgery.

Material and Methods
The study was a prospective, randomised, controlled two-centre study performed at the Regional Centre for Technical Simulation (TechSim), Odense University Hospital, Odense, Denmark and the Copenhagen Academy for Medical Education and Simulation (CAMES), Rigshospitalet, Copenhagen, Denmark. The data was gathered from October 2019 to August 2020.

Participants
The participants were medical students recruited from the University of Southern Denmark, Odense, Denmark and the University of Copenhagen, Copenhagen, Denmark. The inclusion criteria were: 1) a passed exam in the anatomy of the eye, 2) no prior experience with the EyeSi Surgical Simulator, and 3) a Toegepast Natuurwetenschappelijk Onderzoek (TNO) stereoscopic vision test-score (Laméris Utrecht, Ede, Holland) below 240 seconds of arc. Potential participants were invited to undergo an interview to evaluate, if they were motivated and committed to participate, and to ensure that they were fully informed about the extent of the study before entering.

Material
The EyeSi Surgical Simulator (software version 3.4, VRmagic GmbH, Manheim, Germany) was used at both centres. The following modules were investigated (Figure 1): Navigation Training level 2 (Nav2), Bimanual Training level 3 (BimT3), Posterior Hyaloid Training level 3 (PostH3) and ILM peeling level 3 (ILMP3) (Vergmann et al. 2017). The EyeSi Surgical Simulator evaluated each module with a summarized score from 0-100 points. The evaluation was based on target achievement, efficiency, instrument handling, microscope handling, and tissue treatment, except PostH3 which did not contain instrument handling. Measurement of time used to complete each module was performed by the EyeSi Surgical Simulator. (Insert figure 1)
**Intervention**

The participants were equally randomised into two groups. Group 1 performed pretraining of basic skills, until they reached plateau on the performance-curve. Hereafter, both groups received training in the procedure-specific modules until they reached plateau on the performance-curve. Plateau on the performance-curve was defined as completion of three consecutive sessions with the same score with an acceptable variation. This variation was defined as 1) the difference between the lowest and the highest numeric value of the last three scores was ≤10 %, or 2) a new maximum score had not been accomplished in the last three scores. In both definitions, the three scores needed to be above a limit set by the mean score achieved by residents in each module from the original validation study to prevent a premature plateau (limits: Nav2=61.2 points, BimT3=74.0 points, PostH3=7.3 points, and ILMP3=53.3 points) (Vergmann et al. 2017). The primary outcome was time (minutes) used to reach plateau on the performance-curve. The secondary outcomes were starting-score and amplitude of the plateau in the procedure-specific modules.

**Randomisation and blinding**

The randomisation was performed using REDcap (Open Patient data Explorative Network (OPEN)). The randomisation sequence was block randomised using computer algorithm with block sizes of two, four and six. The randomisation sequence was blinded to the researchers. Further blinding was not possible, as the researchers continuously throughout the study needed to evaluate whether each participant had reached plateau. The randomisation was stratified by geographical location.

**Procedure**

Upon enrolment, all participants received a written guideline containing information about practical matters, a summary of their task in the study, an overview of the EyeSi Surgical Simulator instruments, and a step-by-step walkthrough of the modules. The introduction was standardized for all participants and contained gathering of baseline characteristics, a presentation and setup of the instruments on the EyeSi Surgical Simulator, a guide to navigate the EyeSi Surgical Simulator, and self-training with the opportunity to ask the instructor questions. After the introduction, the participants self-trained and were instructed to train minimum once a week and maximum two hours a day to ensure consistent training and prevent fatigue. If ≥21 days between introduction and first training session occurred, the participants were excluded from the study. The participants were contacted throughout the study regarding their progress. In Group 1, the procedure-specific modules were unavailable until plateau was reached in the basic skill training modules to ensure a duly training of the procedure-specific modules.
Uniformity of the recruitment and execution at both centres were ensured via a written guideline and monitoring of the initial introductions by the project manager.

**Statistical analysis**

We estimated the number of participants needed to detect a clinically relevant difference to be n=40. The potential training effect of basic modules is too small to be of any relevance if more than 40 trainees are needed to detect the difference between the two groups. Also, a 20 % dropout was estimated, and the target recruitment was therefore n=48. Throughout the study it became clear, that the dropout percentage increased beyond the anticipated 20 %, and we started to recruit continuously throughout the study to reach target recruitment.

The difference in accumulated time used to complete the procedure-specific modules was compared using a two-sample Wilcoxon rank-sum test. Secondary analyses investigated potential differences in starting scores and plateau levels of the procedure-specific modules, using two-sample Wilcoxon rank-sum test. Of the three scores used to define plateau, the first score was used in the comparison of the plateau level. Results are reported as median with interquartile ranges (IQR).

In all analyses, differences were considered statistically significant with p-values < 0.05. STATA/IC 16.1 (StataCorp, College Station, TX, USA) was used for statistical analyses.

**Ethics**

The Danish Data Protection Agency and the Danish Scientific Ethical Committee both dismissed the need to report the study, as it was not based on personally sensitive or confident information. All the subjects participated voluntarily based on informed consent, and the study was executed in agreement with the Helsinki-declaration. The study was, furthermore, reported on Open Science Framework (OSF) Registries; DOI: 10.17605/OSF.IO/M82TN.

**Results**

A total of 68 participants were included and randomised into Group 1 (n=34: CAMES=19 and TechSim=15) and Group 2 (n=34: CAMES=19 and TechSim=15). There was a 37 % dropout rate (n=25) equally distributed between the two groups (35 % versus 38 %). Consequently, 43 participants completed the study (Figure 2). No statistically significant differences were found between Group 1 and Group 2 regarding number of
participants, location, gender, age, dominant hand, semester, and TNO-score (Table 1). Likewise, there were similar baseline characteristics between the dropped-out participants and the participants who completed the study within the groups (Table 2). (Insert figure 2, Table 1, and Table 2)

The median (IQR) time used in Group 1 to complete the basic skills modules was 88 (58-158) minutes. When comparing the time used to complete the procedure-specific modules between the two groups, the group with the pretraining participants was not statistically significant faster compared to the group of participants with no pretraining (median duration (IQR): 183 minutes (102-246) versus 210 minutes (149-256), p = 0.40, Figure 3).

In the secondary analyses of the starting score in the procedure-specific modules, a statistically significant difference was found between the pretraining group and the non-pretraining group in ILMP3 (median score (IQR) 0 (0-0) points versus 3.5 (0-75) points, p=0.03), but no statistically significant difference was found in PostH3 (median score (IQR) 0 (0-47) points versus 0 (0-14) points, p=1.00). Neither was a statistically significant difference found in the plateau level between the pretraining group and the non-pretraining group in either of the procedure-specific modules: ILMP3 (median score (IQR) 81 (76-86) points versus 79 (72-86) points, p=0.68) and PostH3 (median score (IQR) 86 (79-92) points versus 74 (55-88) points, p=0.14).

When combining the score of both procedure-specific modules, no statistically significant difference was found between the pretraining group and the non-pretraining group in starting score (median score (IQR) 0 (0-75) points versus 34 (0-87) points, p=0.20) nor plateau level (median score (IQR) 163 (155-173) points versus 150 (132-164) points, p=0.08). The results are displayed in Table 3. (Insert table 3)

**Discussion**

In this study, no significant skills transfer was found from the basic skills modules to the procedure-specific module in neither time nor starting score or plateau amplitude. If a positive skill transfer had occurred, one could expect the starting score and plateau level in the procedure-specific modules to be higher in the pretraining group compared to the non-pretraining group. In fact, the quite opposite occurred as the non-pretraining group performed slightly better in the starting score of ILMP3 compared to the pretraining group. Therefore, we can conclude that this study has not been able to show a positive effect of basic skills training transferring to improved performance on the procedure-specific modules.
To investigate a possible clinically significant difference, the time used to reach plateau during basic skills training should be considered. If a clinically relevant positive skill transfer had been taking place in the pretraining group, the training-time on the basic skills modules should not exceed the time the pretraining group had saved in the procedure-specific modules. While the pretraining group was 27 minutes faster in the procedure-specific modules, their median time used in the basic skills modules was 88 minutes. Hence, they used more time completing the basic skills modules than what was saved in the procedure-specific modules, and no clinically relevant difference was found either.

For a positive skill transfer to take place, certain criteria need to be met: a similarity in context, a logical progression of skill, and a similarity in kinematics (Magill & Anderson 2014). In the vitreoretinal training program, a similarity in context is present, as all modules are trained on EyeSi Surgical Simulator. A logical progression of skill is found too, as the basic skills modules are evaluating and teaching isolated skills used in an overall procedural context in the procedure-specific modules. In similarity of kinematics, it becomes more questionable whether the training program is structured for positive inter-procedural skill transfer. The similarities in Nav2 to the procedure-specific modules are clear, as they practise a precise movement needed in both PostH3 and ILMP3. BimT3 practises bimanual handling of the instruments, but the only bimanual requirement in PostH3 and ILMP3 is the ability to refrain from damaging the lens or retina with the light while removing the hyaloid membrane and side-shifting of the instruments. This should be considered in the future development of a vitreoretinal training program: Only psycho-motor skills necessary for performing the procedure should be included.

Currently, the literature in vitreoretinal simulation training on EyeSi Surgical Simulator has been focused on using the training modules to assess competencies in a valid way (Rasmussen et al. 2019; Jaud et al. 2020; Lee et al. 2020). These studies have found the metrics of the EyeSi Surgical Simulator to be capable of discriminating between experienced and inexperienced surgeons. Lee R. et al. (2020) also found studies which showed a learning curve with an overall increase in score and a decrease in completion time with repeated attempts. In the overall development of a vitreoretinal simulation training program on EyeSi Surgical Simulator, our study contributes with an evaluation of the inter-structural design of a training program. The focus in literature on gathering validity evidence for simulation-based tests has left a gap in which we need to investigate how the different modules could ideally be used for training. The current apprentice-model based on “See one, do one, teach one” is limited in its dependence of real patients to obtain increasing complex skills in ophthalmic microsurgical techniques (Khalifa et al. 2006). With an increase in incidence of rhegmatogenous retinal detachment (Nielsen et al. 2020), the need for an efficient
and evidence-based training program in vitreoretinal surgery is emphasized. Starting with more basic part-
tasks before slowly progressing to performing the full procedure can be a sensible approach in a clinical
context, trainees are allowed to learn from their mistakes which can be effective (Dyre et al. 2017).
Skipping basic skills training and proceeding directly to simulation-based training of procedures could
prevent future vitreoretinal surgeons from using time and resources on training with no beneficial effect.

Negative skill transfer occurs when previously learned skills interfere with the learning of a new skill. The
trainee then needs to “unlearn” the previous skill before learning the new. While negative transfer is
temporary, it is time-consuming and frustrating (Magill & Anderson 2014). Figure 3 illustrates that the time
used to achieve plateau in the procedure-specific modules has a wider range in the pretraining group
compared with the non-pretraining group, which would not be expected if skills were transferred from the
basic skills modules. It may however suggest a negative skill transfer. This is emphasized by the significant
difference in starting score of ILMP3, as the non-pretraining group performed better compared to the
pretraining group. Although, this significant difference should be interpreted carefully when considering
the small difference between the groups and limited number of participants in this study. Throughout the
study a frustration was observed from the participants by the investigators, when transferring from the
basic skills to the procedure-specific modules, due to the advances in difficulty when moving from simple to
more complex tasks. It could again be an indication of negative skill transfer, which could be investigated in
future studies. (Insert figure 3)

The paramount test to ensure a successful virtual reality training program, is the degree to which the
learned skills transfer to the real world (Harris et al. 2020). As this study focused on the basic skills modules
as a pretraining tool to procedure-specific modules, further studies in possible skill transfer from the basic
skills modules to the operating room could be interesting. In the overall transfer of skill from a vitreoretinal
training program to the clinical setting, Deuchler et al. (2016) found warm-up training on EyeSi Surgical
Simulator to be an efficient preparation for the surgeons prior to surgery, but more studies investigating
further aspects of the overall skill transfer from a complete virtual reality vitreoretinal training program to
the operating room are needed.

In the study by Vergmann et al. (2017), the participants needed to remove at least 90% of the posterior
hyaloid in PostH3. This boundary was not set in the current study. In generating the total score, EyeSi
Surgical Simulator evaluates damages to the eye more harshly than the amount of remaining posterior
hyaloid. As the participants had access to the EyeSi Surgical Simulator evaluation, it could have led to
speculations in weighing the amount of removed posterior hyaloid against the risk of damaging the eye while doing the removal. Hence, a threshold for removed posterior hyaloid should be applied in future studies and in development of the vitreoretinal training program, to avoid falsely elevated scores from study-participants and insufficient training of aspiring vitreoretinal surgeons.

The study was strengthened by its design, its distinctive investigation of intertransferability within an evidence-based vitreoretinal training program, and the larger number of participants compared to previous studies investigating simulation training in vitreoretinal surgery (Rasmussen et al. 2019). Limitations included the high drop-out (even with no skewness found in characteristics, distribution, or dropout reasons, figure 2 and table 2), the fact that we for practical reasons were not able to include residents of ophthalmology, and the scores the plateau needed to be above. The profoundly lower score in PostH3 could consequently cease to prevent premature plateau taking place. However, the high medians in both groups could indicate that this had not been an issue. Interestingly, the medical students in both groups did relatively well on these advanced surgical procedures which might be related to their young age giving them previous experience with computer games, 3-Dimensional movies etc. (Gupta et al. 2021). Future studies could use threshold scores set by vitreoretinal surgeons, since the threshold did not prevent any of the participants to complete this study.

In this study, we were not able to demonstrate a positive effect of basic skills training on performing procedure-specific modules. We encourage further studies in inter-procedural skill transfer within the EyeSi Surgical Simulator vitreoretinal training program, as this study raises the question whether all modules are necessary in the training of future vitreoretinal surgeons. Furthermore, more studies are needed in the skill transfer from the EyeSi Surgical Simulator vitreoretinal training program to the operating room, prior to implementation of the training program in the curriculum for aspiring vitreoretinal surgeons. Overall, we believe that manufacturers of simulators should focus on making good procedural modules with high realism and pay less attention to arbitrary basic skills modules.

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Conflict of interest
The authors declare that they have no conflicts of interest.

References:


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Figures and figure legends:

Figure 2:
Figure 3:

![Flowchart diagram]

Figure legends:

- Assessed for eligibility (n=76)
  - Did not meet inclusion criteria:
    - Had not passed the eye anatomy exam (n=7)
    - Prior experience with EyeSI (n=1)

Randomized (n=68)

Allocation

Group 1:
Allocated to train abstract and procedure-specific modules (n=34)

Group 2:
Allocated to train procedure-specific modules (n=34)

Follow-Up

Discontinued intervention (n=12)
- Personal matter (n=3)
- Covid-19 outbreak (n=2)
- Stopped answering (n=2)
- Stated it was too time-consuming (n=3)
- Exceeded 21 days after introduction (n=2)

Discontinued intervention (n=13)
- Personal matter (n=5)
- Covid-19 outbreak (n=3)
- Stopped answering (n=3)
- Stated it was too time-consuming (n=3)
- Exceeded 21 days after introduction (n=1)

Analysis

Analysed (n=22)

Analysed (n=21)

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Figure 1: Still images of the training modules. The basic skills modules: Nav2 (1) and BimT3 (2), and the procedure-specific modules: PostH3 (3) and ILMP3 (4)

Figure 2: Flow chart demonstrating the participation flow

Figure 3: No significant difference in time used on procedure-specific modules: Boxplot showing minimum, first quartile, median, third quartile, and maximum of the two groups of participants

Tables:

Table 1: Participant characteristics

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (Pretraining)</th>
<th>Group 2 (No pretraining)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of participants</td>
<td>22</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Location (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TechSim</td>
<td>10 (45 %)</td>
<td>12 (57 %)</td>
<td>0.44</td>
</tr>
<tr>
<td>Gender (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>13 (59 %)</td>
<td>14 (67 %)</td>
<td>0.61</td>
</tr>
<tr>
<td>Age, years (mean)*</td>
<td>24 (21-30)</td>
<td>24 (21-27)</td>
<td>0.78</td>
</tr>
<tr>
<td>Dominant hand (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>19 (86 %)</td>
<td>19 (90 %)</td>
<td>0.61</td>
</tr>
<tr>
<td>Left</td>
<td>3 (14 %)</td>
<td>1 (5 %)</td>
<td></td>
</tr>
<tr>
<td>Both is equal</td>
<td>0</td>
<td>1 (5 %)</td>
<td></td>
</tr>
<tr>
<td>Semester (median)*</td>
<td>7 (6-9)</td>
<td>9 (6-10)</td>
<td>0.45</td>
</tr>
<tr>
<td>TNO-score, sec. of arc (median)*</td>
<td>60 (60-60)</td>
<td>60 (60-60)</td>
<td>0.37</td>
</tr>
</tbody>
</table>

This table reports the characteristics of the analysed participants.

TNO-score: Toegepast Natuurwetenschappelijk Onderzoek (TNO) stereoscopic vision test-score (Laméris Utrecht, Ede, Holland)

sec.: seconds

*mean (range)/median (interquartile range)
Table 2: Comparison of participant characteristics between completed participants and dropouts

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (Pretraining)</th>
<th>Group 2 (No pretraining)</th>
<th>Dropouts (Group 1 vs. Group 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Completed</td>
<td>Dropout</td>
<td>p-value</td>
</tr>
<tr>
<td>No. of participants</td>
<td>22</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Location (n)</td>
<td>TechSim</td>
<td>10 (45 %)</td>
<td>5 (42 %)</td>
</tr>
<tr>
<td>Gender (n)</td>
<td>Female</td>
<td>13 (59 %)</td>
<td>5 (42 %)</td>
</tr>
<tr>
<td>Age, years (mean)*</td>
<td>24 (21-30)</td>
<td>24 (20-30)</td>
<td>0.79</td>
</tr>
<tr>
<td>Dominant hand (n)</td>
<td>Right</td>
<td>19 (86 %)</td>
<td>10 (91 %)</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>3 (14 %)</td>
<td>0 (0 %)</td>
</tr>
<tr>
<td></td>
<td>Both is</td>
<td>0</td>
<td>1 (9 %)</td>
</tr>
<tr>
<td></td>
<td>equal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semester (median)*</td>
<td>7 (6-9)</td>
<td>6 (5-8)</td>
<td>0.62</td>
</tr>
<tr>
<td>TNO-score, sec. of arc (median)*</td>
<td>60 (60-60)</td>
<td>60 (60-60)</td>
<td>0.48</td>
</tr>
</tbody>
</table>

This table reports the comparison of the participant characteristics between the participants who completed the study and the participants who dropped out within the groups. Last column shows the p-value when comparing participant characteristics between group 1 and group 2 of the dropouts.
Table 3: Results of primary outcome and secondary analysis of starting score and plateau level

<table>
<thead>
<tr>
<th></th>
<th>Group 1: Pretraining</th>
<th>Group 2: No pretraining</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time*, minutes</td>
<td>183 (102-246)</td>
<td>210 (149-256)</td>
<td>0.40</td>
</tr>
<tr>
<td>Starting score, points</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PostH3:</td>
<td>0 (0-47)</td>
<td>0 (0-14)</td>
<td>1.00</td>
</tr>
<tr>
<td>ILMP3:</td>
<td>0 (0-0)</td>
<td>3.5 (0-75)</td>
<td>0.03</td>
</tr>
<tr>
<td>Total score:</td>
<td>0 (0-75)</td>
<td>34 (0-87)</td>
<td>0.20</td>
</tr>
<tr>
<td>Plateau level, points</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PostH3:</td>
<td>86 (79-92)</td>
<td>74 (55-88)</td>
<td>0.14</td>
</tr>
<tr>
<td>ILMP3:</td>
<td>81 (76-86)</td>
<td>79 (72-86)</td>
<td>0.68</td>
</tr>
<tr>
<td>Total score:</td>
<td>163 (155-173)</td>
<td>150 (132-164)</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Results are presented as median with interquartile range. The total score is the combined score from both procedure-specific modules (0-200 points).

* Primary outcome: Time used to reach plateau in the procedure-specific modules

Illustrations and graphics:

Figure 1: