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1 **The effect of a simple intra-procedural checklist on the task performance of**
2 **laparoscopic novices**

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1 **Introduction:**

2
3 A checklist has been defined as a comprehensive list of important actions, or steps to be taken
4 in a specific order. It is also used to reduce errors by compensating for potential limits of
5 human memory and attention. It is not believed that checklists prevent all human error and/or
6 accidents but it can decrease errors if it is systematically followed¹. The introduction of a
7 Surgical Safety Checklist by the WHO has significantly reduced the morbidity and mortality
8 of surgery². Checklists are infrequently applied during procedures and have been limited to
9 lists of procedural steps as aid memoires^{3,4}. A common standardised format for training and
10 error reduction is post-procedural paper feedback⁵, however the main limitation of paper
11 feedback is its retrospective post-procedural nature requiring the information being retrieved
12 from memory, often resulting in the loss of finer aspects to feedback.

13
14 We aimed to develop a simple performance based self-administered intra-procedural
15 checklist and to study its effect on the surgical performance of novice surgeons when applied
16 during a standardised laparoscopic task.

17
18 **Methods:**

19
20 A standardised intra-procedural checklist was formulated by consensus among master
21 surgeons who ranked the technical factors influencing the laparoscopic task performance via
22 a link to an online questionnaire. Factors that were taken into account for the design of the
23 checklist included: simplicity, to be short and quick to apply repeatedly, generic items which
24 were non-specific to any procedure, and with greater emphasis on items influencing the
25 performance rather than only aid memoires for steps of the tasks. The checklist was piloted
26 on 10 novices during laparoscopic knot tying prior to the commencement of this study. Based
27 on the results of the total number of errors, the power calculation suggested twenty subjects
28 should enable the detection of 20% difference of median total number of errors with 80%
29 power at 5% level.

30
31 Following the completion of the pilot study, twenty consented novices from medical students
32 and junior doctors without any previous laparoscopic experience were randomly allocated in
33 two equal groups using an online randomiser software. The control group received a
34 standardised post-procedural paper feedback alone, and the checklist group received the post-
35 procedural paper feedback in addition to the standardised checklist. A beeping sound was
36 used at 20 seconds intervals in order to remind novices to apply the checklist that was
37 displayed beside the laparoscopic monitor at eye level. A standardised paper feedback was
38 applied to both arms of the trial, as the current gold standard, in order to study the effect of
39 the checklist.

40
41 Each candidate was given a 10 minutes introductory training to perform the task of double
42 square knots. The task was divided into 4 subtasks: i) creation of a C-shaped configuration of
43 the suture thread for creating the first double throw, ii) configuration of the first double
44 throw, iii) creation of a reverse C-shaped configuration for creating the second double throw,
45 iv) configuration of the reverse double throw.

46
47 Every participant performed the laparoscopic task on a synthetic material in five separate
48 stages. The duration of every stage was 3 minutes, and was followed by a 3 minutes rest. The
49 tasks were in a Laparoscopic Endo trainer (26348 SZABO-BERCI-SACKIER laparoscopic
50 trainer) using 2 needle holders (26173KAF, KOH Macro Needle Holder, 5mm diameter, 3cm

1 length, Karl Storz) and a telescope (26003BA, Hopkins ®, 30 degree, 10mm diameter, 31 cm
2 length, Karl Storz)

3
4 Novices were randomised by using an online randomiser. Unedited video recordings were
5 analysed by the Human Reliability Technique⁶. The unedited videos were analysed for
6 surgical task performance by the main assessor who was blind to the categorisations of the
7 arms.

8
9 Endpoints were total number of errors during each task, error frequency also known as error
10 probability for each task (total number of errors per total number of knots), error types, and
11 number of completed knots. Non-parametric Mann–Whitney U and Wilcoxon tests were used
12 for statistical analysis. Comparative data were presented as median (IQR).

13 14 **Results:**

15
16 Fourteen master surgeons ranked the technical factors influencing the laparoscopic task
17 performance via an online questionnaire. This revealed the following order from the most to
18 the least important: 1-Exposure, 2-Bi-manual coordination, 3-Degree of force, 4- Direction of
19 force, 5-Following the steps of the task and 6- Speed (Figure 1).

20
21 Exposure was the highest ranked factor, however, it was excluded in this study due to the
22 standardization of the obtained optical view. In addition, direction of force was excluded
23 because it could not be taught to novices with no previous laparoscopic experience. A pilot
24 study on 10 novices revealed that ‘speed’ was practically the most important factor that
25 improved their performance, therefore it was ordered first on the checklist. The components
26 of the checklist were worded as shown in figure 2.

27
28 Twenty laparoscopic novices were included in this study. Eight were males and 18 were right
29 handed (Figure 3). 2341 errors were detected in 141 tasks and 408 subtasks during the 5
30 stages. There were 1422/2341 errors (60.75 %) in the control group (those who received
31 paper feedback only); as compared to 919/2341 errors (39.25%) in the checklist group (those
32 who received both the checklist and paper feedback). During the first stage, the errors were
33 not significantly different between the two groups. The checklist group committed
34 significantly fewer errors as compared to the control group during all the later 4 stages
35 ($p<0.01$) (Figure 4).

36
37 The checklist group had an enhanced learning curve as the last 4 stages showed significant
38 fewer errors compared to the first stage ($p<0.05$). The control group showed no improvement.
39 Error probability was significantly higher in the control group compared to the checklist
40 group [median (IQR) 32.6 (25.89) vs 11.7 (10.72) ($p<0.01$)].

41
42 Individual error types during each step of the laparoscopic task were identified. The checklist
43 group performed better with fewer errors for all the error types. While, there was no
44 significant difference in each of ‘the lack of supination’, ‘tissue bite’ and ‘out of vision’; the
45 differences in all the rest of error types were highly statistically significant ($p<0.01$) (Table
46 1). Number of completed knots was not statistically different between the 2 groups.

1 **Discussion:**

2
3 Our simple performance based intra-procedural checklist appears to have a significant
4 accelerating effect on the acquisition of technical skills when applied by novices during a
5 standardised lab-based laparoscopic task. This is the first study to look at a surgical checklist
6 that is simple to be applied, mainly performance based, and used during surgery.
7

8 The introduction of a Surgical Safety Checklist by the WHO has significantly reduced the
9 morbidity and mortality of surgery². The 19 items surgical checklist ensures that essential
10 information such as patient identity, the type of procedure, its risks and other patient factors
11 are brought to the team's attention. This synchronization of essential information is
12 accompanied by an introduction of all team members by name and role in the operating
13 theatre. The WHO surgical checklist may prevent avoidable human error, however, it is only
14 limited to pre-and post-procedural evaluation.
15

16 There are only few previous studies that have looked at the effect of checklists during routine
17 surgical procedures. Intra-procedural checklist has been loosely defined by different authors.
18 Robb WB *et al* studied the effect of an intraoperative surgical aid memoire on the conversion
19 rates from laparoscopic to open cholecystectomy³. In this study, the checklist was used as an
20 indirect measure of error reduction, limited to parts of a specific procedure (cholecystectomy)
21 and was only used as aid memoire for procedural steps. Ziewacz JE *et al* studied the design,
22 development, and implementation of an algorithm for intraoperative neuro-monitoring
23 changes⁴. It highlighted the specific roles of the anaesthetist, surgeon, and neuro-monitoring
24 personnel during neuro-spinal procedures and the clinical efficacy of this remains unknown.
25

26 The performance of laparoscopic surgery is often more difficult for novices when compared
27 to open procedures. There are potentially several reasons for this, which may include poor
28 image quality and its magnification, difficulty with depth perception⁷ and the need to
29 interpret the 2D image into 3D in laparoscopic surgery. The fulcrum effect of the
30 laparoscopic instrument⁸, lack of haptic feedback⁹, and unfamiliarity with the angular view
31 might also make laparoscopic surgery more difficult than open.
32

33 Our checklist is short and simple, made of four factors making it easy to remember and quick
34 to apply by novices repeatedly. The simplicity of the checklist minimizes its potential
35 interference as a distraction during the procedure. Performing the procedure in a step wise
36 fashion in a correct order has been the focus of previous studies. Our checklist included this
37 important factor but critically also included additional factors influencing the task
38 performance itself. The checklist is based on generic factors which makes it applicable to
39 most surgical procedures. The application of a mainly performance based checklist will result
40 in error reduction rather than error correction, i.e. minimizes the occurrence of errors. It is the
41 authors' opinion that experts tend to apply our simple four point checklist at regular intervals
42 often unknowingly, however, it takes time and practice for the novices to be able to apply
43 these points automatically when appropriate.
44

45 Novices tend to operate at the same rate throughout all stages of the procedure regardless of
46 its difficulty. It is generally advisable for novices to operate at slower rate to reduce errors,
47 particularly in high risk zones of the procedure. Reminding the novices to slow down through
48 the application of the checklist will have the desired effect as shown in this study.
49

1 During the intensive concentration required for performing laparoscopic tasks, novices often
2 ignore their non-dominant hand at the expense of the dominant one. A typical scenario arises
3 when a novice surgeon fails to adequately retract the tissue using the instrument in the non-
4 dominant hand resulting in poor exposure for the dissection performed through the instrument
5 in their dominant one. Reminding the novice to use both hands optimally has the potential
6 advantage of making the surgeons operate bimanually.

7
8 An important independent factor for the performance in laparoscopic surgery is the degree of
9 force applied to the tissue using the instrument, with too little force often resulting in
10 repeating the steps, or too much force giving rise to errors with consequence, such as
11 bleeding or tissue tear. The novices need guidance throughout the procedure over time to
12 understand the appropriate degree of force required to achieve the task. For a novice, it is
13 safer to be gentle in order to minimize any errors with consequence.

14
15 The checklist group performed better in five out of eight error types. Although the link
16 between the individual error types and the checklist components was not the focus of this
17 study, there appears to be a relationship between the individual checklist items and certain
18 error types. For example, being asked to be gentle resulted in committing fewer errors
19 defined as ‘‘inappropriate degree of force’’ and ‘‘wrong direction of force’’. There were
20 significant improvements in the checklist group for ‘‘ inappropriate instrument positioning’’
21 and the ‘‘inappropriate grip of suture material’’. This could have been corrected by the two
22 components of the checklist, ‘‘slowing down’’ and ‘‘using both hands together’’. Being
23 asked to follow the steps could be resulted in committing fewer ‘‘missed steps’’.

24
25 Although novices were asked to perform the tasks slowly, they managed to successfully
26 complete the same number of knots with fewer errors. As in general, the accuracy of a
27 movement tends to decrease when its speed increases above a threshold¹⁰. Our interpretation
28 is that slowing down could give the participants more time for visual feedback¹¹. For the sake
29 of standardization, we used a beeping sound to remind novices to apply the checklist.

30
31 We envisage that novices will be able to apply the checklist on their own or simply prompted
32 by the trainer after completing the initial standardized training. Because of the non-obtrusive
33 and simple format of the checklist, we envisage that it can also be displayed for viewing by
34 the surgical trainee during live surgery in the operating room. The effect of the checklist on
35 the acquisition of laparoscopic skills in the operating rooms could be the subject of future
36 studies.

37 38 **Conclusions:**

39
40 This simple performance based intra-procedural checklist appears to have a significant
41 accelerating effect on the acquisition of technical skills when applied by novices during a
42 standardised lab-based laparoscopic task. Our checklist can be applicable during lab-based
43 training by surgical novices.

44 45 **Disclosures:**

46
47 The authors declare no conflict of interests.

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2

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5

6 **Ethical approval:**

7

8 Approval was granted by local research ethics committee prior to the commencement of this
9 study.

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