Defining parameters for objective assessment of technical skills in a transanal purse string suture

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OBJECTIVE—Objective skill assessment minimally invasive surgery is mostly limited to simple laparoscopic tasks. There is a gap regarding single port procedures. Transanal total mesorectal excision (TaTME) is a novel procedure with a purse string suture as one of the critical steps. This study aims to identify potential relevant metrics for objective skill assessment in a transanal purse string suture. A box trainer that measures forces at the entrance port is designed and a construct validity study is performed to define the validity of the proposed metrics. METHODS—A box trainer that allows suspension of a calf’s intestine is designed. A novel measurement system in the port is developed. This system measures the applied forces (port inwards, Fz) and moments on the entrance port. Tissue interaction forces are also measured. With this trainer 3 experts and 7 novice participants performed a purse string suture to test if these parameters can indicate instrument handling skills of the participants. RESULTS—The results show that significant difference exist between novice pre- and post-training for minimal Fz, mean Fz, ratio push and pull in Z. Also, the minimal, mean and ratio positive/negative moment about the x-axis show significant differences. Mean, and ratio in Fz also shows significant results, although with low power, between novice pre-training and experts. The standard deviation (SD) of tissue interaction force also shows difference between novice pre-training and expert. CONCLUSION—This study shows that forces and internal moments in the port can give insight in instrument handling skills and tissue interaction force signatures can be used as an indication of experience in a transanal purse string suture.

Index Terms—box trainer, skill assessment, objective assessment, parameters, TME, total mesorectal excision, purse string suture, TaTME, transanal total mesorectal excision.

I. INTRODUCTION

A. Background

Since the first mention of the role of the mesorectum in rectal cancer recurrence a Total mesorectal Excision (TME) has been the status quo for curative surgery for most stage II and stage III rectal cancers.1,2 For less invasive surgical procedures in the rectum Transanal Endoscopic Microsurgery (TEM) and Transanal Minimally Invasive Surgery (TAMIS) are still widely used procedures.3,4 In laparoscopic TME difficulties for the surgeon arise when the patient is obese or the cancer is situated low in the narrowing pelvis.5 Therefore a two-team approach is being studied, where the TME is performed both laparoscopically and using TAMIS: the Transanal Total Mesorectal Excision (TaTME). The rectum is entered transanally using a GelPOINT access platform Path (Applied Medical, Rancho Santa Margarita, CA, USA) using general linear laparoscopic instruments. First experience, and preliminary result in clinical trial has already shown that TaTME does not compromise clinical outcome.6,7 However, the procedure does create the need for new skills for the surgeon. Because of the bottom-up approach anatomical landmarks are approached differently which can cause the surgeon to get lost during the procedure. This creates a risk of nerve and organ damage.8 Furthermore problems with anal dysfunction is still an issue for transanal procedures such as these.9 The necessity for proper training has therefore been acknowledged early on in the development of the procedure.10 Currently education is done through cadaver-training and in-house proctoring.11,12 There is, however, a lack of objective assessment of operating skills for this procedure. Not only because it is novel, but because research into objective skill assessment in surgery focusses mainly on basic skills in general laparoscopy. Single port procedures and procedural tasks are overlooked.13 The lack of research in this field gives way for research into ways to monitor and train surgeons objectively for this specific procedure.

B. Purse String Suture

A critical step in TaTME is the transanal purse string suture (TaPSS). As the name implies it is a 360° round suture to tie the bowel. It is used to tie the bowel distally of the tumour before full-thickness incision of the rectum. Apart from indicating the distal resection margin, the suture ensures closing of the cut stump of the rectum, preventing leaking of bowel fluids into the abdomen.14 Observation at a two-day TaTME course revealed there are various factors known that contribute to a well, or badly placed TaPSS. The number of stitches is said to relate to good closure. About twelve stitches is used as a baseline. Furthermore, spiraling of the suture has to be minimized. Last the location of the stitches relative to one another is critical to allow properly pulling the bowel tight.

C. Study objective

The lack of research into objective skill assessment in single port surgery and the knowledge that the TaPSS is a crucial step in TaTME give reason for the research question of this study: What are potential parameters for objective assessment of skills when performing a transanal purse string suture?

The goal of this study is the design of a box trainer that measures forces applied on the entrance port, as well as tissue interaction forces while performing a TaPSS to investigate if
these metrics show potential for use as metrics for assessment of technical skill for this task. To show the potential of the proposed metrics a study between surgeons experienced in TaTME and surgeons with experience only in general laparoscopy will be performed.

II. MATERIALS AND METHODS

A. Trainer requirements

The device must be designed as an addition to the LapStar laparoscopic box trainer (Camtronics, Son, NL). This box trainer is currently used for laparoscopic skills training and research at VU medical center Amsterdam. The trainer should allow application of the GelPoint Path transanal port (Applied Medical, Rancho Santa Margarita, CA, USA) that is used in OR for the TaTME procedure. Calf’s intestine will be used as a specimen, so cleanliness of the trainer is crucial. The setup must allow insufflation to create workspace in the lumen.

Observation in the OR and at the TaTME course has given insight in instrument handling and configuration. The purse string suture runs all the way around along the wall of the bowel. It is therefore expected that torque is will be applied about the x and y axis of the port due to instrument configuration (Figure 1) The trainer must therefore measure forces exerted in the port in three directions and permit computation of moments about x-axis and y-axis (Figure 1). Horeman et al. previously discussed the importance of tissue interaction forces in laparoscopic skill assessment. Therefore, this system should also allow measurement of tissue interaction forces using a ForceTrap measurement system (Medishield, Delft, NL).

B. Hardware and software

According to set requirements the LapStar box trainer is equipped with a novel measurement system (Figure 2) to measure force parameters. The GelPoint path (Figure 2 A) can be attached to the front of the box onto a measurement platform to analyze instrument handling forces in the port. At the back of the measurement port the bowel (Figure 2 C) is attached. The dummy is tied using a piece of suture thread to allow for insufflation. A rigid connection (Figure 2 D) to the ForceTrap (Figure 2 E) is designed. G shows the wiring connecting the sensors to the data acquisition device, the system to the laptop and tablet.

A detailed depiction of the measurement port can be seen in Figure 3. The GelPoint Path is fixated in a central tube (Figure 3 E) that is connected rigidly to an inner ring (Figure 3 F). Two parallelogram constructions allow for 1DOF along both x-axis and y-axis are created using blade springs (Figure 3 B,C). This concept is mounted onto a base plate to allow force measurements when torque is applied to the port. From these measurements internal moments about x-axis and y-axis can be calculated. Five solid state hall effect sensors model SS495A (Honeywell, Fresport, USA), each accompanied by a magnet (Ø3mm, thickness 2mm) are incorporated to measure deflection of the system in x, y and z (3x). Deflection is measured in Volt output and will be calibrated for the force that was needed for that deflection. Output of the sensors is collected using a LabJack U3 DAQ (LabJack Corporation, Lakewood, CO, USA) and written into text files with a sampling frequency of 50Hz. Tissue interaction force data is collected with the accompanying software with the ForceTrap. Written directly into the online environment of the system with a sampling frequency of 50Hz.

Structural components (Figure 2, B D) are hand made at the workshop at the 3mE faculty at Delft University of Technology.

Figure 1 Surgeons training on cadaver at TaTME course January 2018. In an overlay the proposed axial system is noted. Included are the expected torques about the x and y axis.


Figure 3 Port configuration. A– GelPoint Path. B,C,D,F– ring and spring constructions that create two parallelogram configurations in x and y direction. E– locked tube for fixation of GelPoint Path. G,H– plate and spring configuration for translation in z direction.
C. Parameters

Table 1 shows a complete list of proposed parameters, a detailed depiction of parameters in defined in the port is seen in Figure 4. Multiple characteristics are analyzed per parameter: the minimal output, maximum output, mean and standard deviation (SD).

<table>
<thead>
<tr>
<th>Location</th>
<th>Parameter</th>
<th>Characteristic</th>
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<tbody>
<tr>
<td>Tissue interaction force</td>
<td>Fz</td>
<td>max, mean, SD</td>
</tr>
<tr>
<td>Forces in port</td>
<td>Fx</td>
<td>min, max, mean, SD</td>
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<td></td>
<td>Fy</td>
<td>min, max, mean, SD</td>
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<td></td>
<td>Fz</td>
<td>min, max, mean, SD</td>
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<td></td>
<td>Fz.pos</td>
<td>ratio, mean, SD</td>
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<td>Fz.neg</td>
<td>mean, SD</td>
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<tr>
<td>Internal moments in port</td>
<td>Mx</td>
<td>min, max, mean, SD</td>
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<tr>
<td></td>
<td>Mx.pos</td>
<td>ratio, mean, SD</td>
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<td>Mx.neg</td>
<td>mean, SD</td>
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<td></td>
<td>My</td>
<td>min, max, mean, SD</td>
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<td></td>
<td>My.pos</td>
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<td>My.neg</td>
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<td></td>
<td>M.res</td>
<td>max, mean, SD</td>
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For Fz, Mx and My in the port the ratio between the amount of time output is positive or negative: Fz.pos, Mx.pos and My.pos. In other words: how much task time is spent pushing port inwards (Fz.pos), or applying torque in a certain direction (Mx.pos and My.pos). It is expected that these parameters can contain information on instrument handling.

The resultant force in z-direction in the port is calculated from the Z1, Z2 and Z3 components in the port (Figure 4) using Equation (1).

\[ F_z [N] = F_{Z1} + F_{Z2} + F_{Z3} \]  

\[ F_{Z1} = 125.9 - 1.07 \cdot 10^{-3} \sqrt{V} \cdot 8.37 \cdot 10^9 - 1.05 \cdot 10^{10} \quad 2.5 \leq x \leq 4.9 \]  

\[ F_{Z2} = 39.8 - 3.48 \cdot 10^{-4} \sqrt{V} \cdot 3.32 \cdot 10^{10} - 8.10 \cdot 10^{16} \quad 2.5 \leq x \leq 3.2 \]  

\[ F_{Z3} = 15.16 - 4.88 \cdot 10^{-5} \sqrt{V} \cdot 4.09 \cdot 10^{11} - 1.09 \cdot 10^{12} \quad 2.5 \leq x \leq 4.1 \]

The moments in the port are calculated by Equation (2), (3) and (4):

\[ M_x [Nm] = 49.36 \cdot 10^{-3} (F_{Z2} - F_{Z3}) \]  

\[ M_y [Nm] = 28.5 \cdot 10^{-3} (F_{Z2} + F_{Z3}) - (57 \cdot 10^{-3} F_{Z1}) \]  

\[ M_{res} [Nm] = \sqrt{M_x^2 + M_y^2} \]  

Furthermore, tissue interaction force (Fz.t) and task time are studied. Fz is an absolute value, therefore no minimum value is analyzed.

D. Calibration

1) Methods

Because of mechanical failure of the springs for sensors x and y in the port it is chosen to only calibrate for sensor Z1, Z2 and Z3. The ForceTrap is already calibrated, a change in measurement output corresponds direct linearly to a measured force.

The force-voltage relationship for sensor Z1, Z2 and Z3 was determined by applying a known force to the port in line with the z-axis. Because of the radial symmetry in the configuration (Figure 4) it is assumed that the applied force divides evenly over the three sensors. Therefore:

\[ F_{Z1} = F_{Z2} = F_{Z3} = \frac{1}{3} F_w \]  

A weight is suspended to the port in steps of 0.1kg, from -2.5kg (box out) to +2kg (box in). Every measurement is run for 30 seconds. The average measured voltage is noted as the correponding voltage to the at that time applied force.

2) Equation fit

A trendline of the calibration plot is fitted by a second-degree polynomial, Equation (6). The obtained constants and equations care obtained in MS Excel 2016.

\[ y = (c_2 \cdot x^2) + (c_1 \cdot x) + b \]  

The inverse of obtained second degree polynomials makes an equation for force as a function of voltage output, as seen in Equation (7), (8) and (9). These equations are used to fit the measured voltages during the experiment to an applied force. The range of the equations is set to the minimum and maximum measured voltage during the calibration because the force-voltage ratio outside the observed voltages becomes inaccurate to predict.
In partial fulfilment of the requirements for the degree of Master of Science in Biomedical Engineering at Delft University of Technology.

E. Construct validity

1) Equipment
Participants will work on the previously described test setup. A calf’s colon is used as specimen, the setup will therefore be wrapped in cling foil to prevent contamination. Every participant is handed a new suture set to ensure same sharpness of the needle for every participant. A 30° laparoscope (Olympus, Tokyo, Japan). Regular linear laparoscopic instruments are used: scissors, curved grasper and needle driver. Data is collected on a laptop using LJStreamUD (LabJack Corporation, Lakewood, CO, USA), and a MS Surface (Microsoft, Redmond, WA, USA) using ForceTrap software (Medishield, Delft, NL).

2) Participants
Participants are recruited at the TaTME course of 31 January and 1 February 2018. Subjects are grouped by to experience with a transanal purse string suture. Participants with experience of 0 to 10 purse string sutures are considered novices, those with experience of more than 50 transanal purse string sutures are considered expert. Intermediate (11-50 sutures) participants are excluded from this study. Furthermore, the experience of the laparoscopist is considered. A laparoscopist with experience with a 30-degree scope of more than 20 times is considered expert, less experienced are considered novice. This information will be obtained through a questionnaire prior to the training.

3) Task
A full purse string suture consists of running the suture 360° along the wall of the bowel, with the last stitch overlapping the first to ensure full circumference of the bowel. Then the suture is pulled tight, closing the lumen, and tied with a surgical knot. For this study the participants are asked to perform only the suture part of the task. This is done to ensure that the measurements are influenced by only the suture part and data is interpreted correctly.

4) Protocol
Before participation each participant is asked to fill in a questionnaire regarding their experience in various aspects of laparoscopic surgery. Participants are all clearly instructed before starting the measurements. They are specifically asked to start the suture at the bottom (6 o’clock and work clockwise. It is emphasized not to tighten the suture and not to tie a knot. Both measurements systems are started before the participant starts the suture. A tic is given to both measurement systems at of the first stitch to allow data synchronization of the data afterwards.

5) Data analysis
Data is obtained in .txt files with two different programs. The online environment of the ForceTrap for tissue interaction data, and LJStreamUD for port data. The data is afterwards imported in MS excel 2016 for visualization and manual synchronization. Statistical analysis is done in SPSS Statistics 24 (IBM, North Castle, NY, USA). First a Kolmogorov-Smirnov test for normality will be done. Then a paired samples T-test between the novice group before and after the course and two independent samples T-test between the different novice groups and expert group will be done. Comparison of the novice groups with experts will be interpreted as preliminary results because of the low sample size of the expert group.

III. Results
Two groups are defined based on the questionnaire: Novice (n=7), experts (n=3). All participants where right-handed males. One novice participant performed the TaPSS counterclockwise, pre- and post-training. Two groups of laparoscopy expertise are defined based on the questionnaire. All novice surgeons were accompanied by an expert laparoscopist. The expert surgeons were accompanied by a novice laparoscopist. Figure 5, Figure 6, Figure 7, Figure 8, Figure 9 and Figure 10 show scatter plots of the distributions of all parameters per experimental group.

Kolmogorov-Smirnov tests for normality showed that data for Fz,SD and Time was not normally distributed for novice pre-training. The same holds for Fz.pos.mean in novice post-training. The sample size of experts is too small to determine normality of the data.

Paired samples T-test comparing novice pre- and post-training showed significant changes for some characteristics of Fz in the port (Figure 5) minimum (4.1, 6, p<0.01), mean (-5.3, 6, p<0.01), positive-negative ratio (Fz.pos) (-6.0, 6, p<0.01), Fz.neg.mean (-3.3, 6, p=0.02) and Fz.neg.SD (3.1, 6, p=0.02). Also The moment about x (Figure 6) showed significant differences for some characteristics: minimum (Mx.min) (2.8,6,p=0.03), mean (Mx.mean) (2.5,6,p=0.05), positive-negative ratio (Mx.pos) (3.7,6,p=0.01) Mx.neg (-3.7,6,p=0.01), Mx.neg.mean (3.7,6,p=0.01), Mx.neg.SD (-2.8,6=0.03).

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<th>Parameter</th>
<th>PRE-POST</th>
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<td>My.neg.SD</td>
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<td>Mres.SD</td>
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<td>Fft.SD</td>
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<td>Time</td>
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*p<0.05, **p<0.01, ***p<0.001, ( ) indicates that statistical analysis has been done but power was low because of low expert group size.
Figure 5 Distribution for characteristics of Fz in port for novice pre, novice post and expert measurement. * p<0.05, ** p<0.01, *** p<0.001. ( ) indicates that statistical analysis has been done but power was low because of low expert group size.
In partial fulfilment of the requirements for the degree of Master of Science in Biomedical Engineering at Delft University of Technology.

Figure 6 Distributions for characteristics of Mx in port for novice pre, novice post and expert measurement. * p<0.05, ** p<0.01.
Figure 7 Distributions for characteristics of My in port for novice pre, novice post and expert measurement. **p<0.01, ( ) indicates that statistical analysis has been done but power was low because of low expert group size.
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Figure 8 Distributions for characteristics of the Resultant Moment (Mres) in port for novice pre, novice post and expert measurement. * p<0.05, ( ) indicates that statistical analysis has been done but power was low because of low expert group size.

Figure 9 Distributions for characteristics of Tissue Interaction Force (Ftt) for novice pre, novice post and expert measurement. * p<0.05, ( ) indicates that statistical analysis has been done but power was low because of low expert group size.

Figure 10 Distribution for Task Time for novice pre, novice post and expert measurement. * p<0.05, ( ) indicates that statistical analysis has been done but power was low because of low expert group size.
IV. DISCUSSION

A. Most important results

The most notable results seen are first the changes in the mean force applied to the port, and the ratio of this force being positive or negative. Furthermore, the lack of difference in task time is an interesting observation. Also, the observation that significant changes in moment about the x-axis (vertical) are noticed but not about the y-axis (horizontal). Last the fact that task time did not change significantly is noteworthy.

B. Task time

According to pilot results it is expected that task time will be higher for novice than experts. Post hoc power analysis shows that power of the study is very low (1-β<0.2). Also, the novice pre-training data is not normally distributed. Observation of the scatter plot (Figure 10) does show a decline for novice post-training to experts as expected. When considering the one high measurement in novice pre-training as an outlier, task time even seems to go up slightly in the novice post measurement. This might be an effect of showing off in the first round to complete the task fast. Another possible explanation is the presence of experts during the post measurements, which might have created more caution in novices’ behavior and therefore slowing them down. It can also be a learning effect of the training day. It is possible that novices are a lot more aware of their actions during the second run, trying to apply the just learned techniques properly which causes a decline in their task time. A follow up study with these participants could give more insight in this learning curve when the taught techniques become more

C. Tissue interaction force [Suture site]

Previous research suggests that tissue interaction force is a valid assessment parameter for skills assessment in surgical tasks.\textsuperscript{16,17} Although a trend is observed in the obtained the power of this study is too low (1-β<0.2) to observe statistically significant results for the maximum and mean tissue interaction force (F_t, Figure 9). F_t.SD however does show a significant decline between novice pre-training and experts. It is expected that with a higher sample size and strict protocol this data can become more interesting as an assessment metric.

When observing the raw data however, interesting differences can be seen. Figure 11 shows the raw data of three novice and three experts. Force peaks applied by novice are longer (les ‘spikey’) than those of experts. This also correlates to

![Figure 11 Raw data plots of tissue interaction force of novice pre-training (above) and experts (below). The lines indicate critical values where tissue damage appears in a porcine large bowel.](image-url)
the observed techniques used by experts compared to
difficulties for novice to correctly insert the needle through the
tissue. Experts are seen to actively transfer the needle between
the instruments, creating one smooth motion, having the needle
directly in the right plane for insertion. Novice do not use this
technique yet which causes them to ‘poke’ the tissue multiple
times before actually setting a stitch. This causes them to apply
a force on the tissue for a longer period than experts. This
behavior can be interesting as a measure of instrument handling
skills.

Horeman et al.\textsuperscript{18} showed that tissue damage appears quite
quickly in porcine intestines when pulling a suture. The
thresholds for the first sign of damage (1.3N, dotted line), and
actual rupture (1.8N, full line) are visualized in Figure 11.
Novice participants exceed these forces a lot more than experts
do. This shows that practicing this suture outside of the OR is
highly recommended.

D. Force on port in- and outward [Port site]
The mean resultant force (Fz.mean, Figure 5) on the port
applied box inwards is significantly higher for experts than for
novice both pre and post training. It even shifts from negative,
which implies a pulling motion on the port, to a positive value,
which implies a pushing force on the port. This is also observed
in the ratio between a pulling and pushing force during the task
(Fz.pos, Figure 5). This shows that the expert group exerted a
pushing force 60% to 90% of the time, where for novice pre-
training this was the direct opposite, namely only 10% to 40%
of the time. This suggests that there is a different in instrument
handling between experts and novice that makes for novice to
pull on the port more than experts. It is possible that this is
cased by difficulties in instrument handling by novice behind
the port (inside the lumen). The instruments are not always
entirely visible through the laparoscope, which can cause
collision of instruments going unnoticed by the operating
surgeon.

These collisions might be a cause for clamping the
instruments in the port and when put in motion, instead of
having them run through the trocar smoothly, pulling the entire
port towards the surgeon. There are no previous studies,
however there is a possibility that applied force correlates to
clinical outcome in regarding anal function. The clear changes
in behaviour, however, can be of value for objective assessment
of expertise. More extensive research is needed to determine the
relevance.

E. Internal moments [Port site]
Because of 360° motion that is made when performing the
TaPSS it is expected that the internal moments in the port will
shift according to the position of the instruments at a certain
moment. Because participants were asked to all perform the
suture clockwise, a specific change in moments is expected as
seen in. This distinguishing shape is in the raw data seen in My,
but less for Mx. It is possible that this is effect is due to input of
the laparoscopist. Because they are operating side by side
through the one port is possible that the scope, which is held
steady, inhibits rotation of the port around the x-axis. The fact
that it is the negative moment makes sense since the
laparoscopist is sitting to the right of the surgeon, therefore
keeping a steady force in the positive x direction, counteracting
the negative moment. Also, the scope is more or less positioned
‘through’ the y-axis, therefore not influencing the moment
about it. Taking a closer look at Figure 12 shows that in phase
D the suture is being placed in the right side of the bowel. This
is also the side where the scope enters the lumen. Comparing
the phases in Figure 12 and Figure 13 suggests that interference

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure12.png}
\caption{Figure 12 Expected change of internal moments during the suture. Above images represent the front-view of the GelPoint Path with an instrument inserted. Starting the suture at the bottom (A) continuing clockwise (B to D). The X marks the location of the laparoscopist.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure13.png}
\caption{Figure 13 Trajectory of moments about x-axis and y-axis of one expert (red) and one novice pre-training (blue).}
\end{figure}
of the scope with the instruments causes these changes in behavior about the x-axis. This can therefore be a potential measure for efficient instrument use during the TaPSS.

Although no significant results are found, the scatter plots of My.min and My.max suggest that rotation about the y-axis will converge to a specific angle of approach with increase in experience. It is likely however that the height of the surgeon’s chair or height of the table have an influence on this value of this asymptote. This must be evaluated in a more comprehensive study.

The theory that the laparoscope is a main cause for differences in moments about the two axes, it is interesting to link the experience of the laparoscopist. Two levels of laparoscopist have participated in the teams. All novices were accompanied by someone considered an expert, all experts were accompanied by a novice laparoscopist. The fact that the expert group was accompanied by a novice laparoscopist might explain the slight rise in Mx.min, Mx.max and Mx.mean (Figure 6) for experts compared to novice post-training.

![Positioning of instruments and laparoscope in the GelPoint Path](image)

Figure 14 Positioning of instruments and laparoscope in the GelPoint Path trananal access port.

To the knowledge of the author no research has been done into the influence of port handling on clinical outcomes regarding anal function. Fecal incontinence was a concern when first introduced but seems to have little impact on quality of life long after surgery.\(^\text{19,20,21}\) The dysfunction that is noted, however is linked mostly to operating time. It can be of interest to assess clinical outcome related to port handling.

**F. Limitations of this study and future research**

In contrast to the dummy bowel used in the pilot study the calf’s intestine made it difficult to observe if the suture is being placed neatly in-plane or skewed. Also, the number of stitches is difficult to tell because of the fatty tissue surrounding the specimen. Since these are seemingly important parameters for a sufficient purse string suture (Dr J. Tuynman) it can be considered to develop a way to still observe these aspects. This cannot be done by (post-task / manual) video assessment.

After participant A (intermediate), B, C and D (pre-training novices) the springs in x and y direction of the port buckled. This caused for loss of the two parameters and therefore in-plane forces in the port could not be assessed. However, data collected from sensors Z1, Z2 and Z3, including moment assessment, give seemingly relevant information regarding tool-port interaction. The new metrics defined in terms of internal moments are novel in this field of study and give way for interesting further research.

Only three experts participated in this study. This makes power of the statistical analysis low and outcomes should therefore be interpreted accordingly. Future research should aim for a larger group of expert participants.

A previously performed literature study\(^\text{13}\) suggests that actions of the surgeon’s body can be of relevance for determining skill level. Since the posture, and hand positioning is much different in TaTME than in general laparoscopy this can also be interesting for future research.

**G. Relevance of trainer for TaTME**

It has long been said that training surgical skills outside of the OR is beneficial over usual apprenticeship model.\(^\text{22,23}\) Also objective assessment seems feasible when identifying the right metrics for a task.\(^\text{17,24}\) Various types of physical box trainers have long been commercially available and used in medical training, and more and more apply objective skill assessment and feedback. However no commercially available single port, not to mention transanal access, trainers that apply this objective assessment are found in literature. [source, lit study]. Keep in mind that TaTME is currently educated in theatre and on cadavers. Also because of the novelty of this procedure gathering knowledge about what makes a good procedure is ongoing and subjective. Therefore, this device can be of value for efficiency and cost effectiveness of training (parts of) TaTME.

Furthermore, the novel measurement port designed for this study gives unique insights in instrument handling behavior in the GelPoint Path because of the configuration of three separate sensors. Parameters regarding the internal moments created in the port site are, to the best knowledge of the writer, not yet examined in terms of objective assessment of instrument handling skills. These parameters cannot be obtained with the ForceTrap that is currently used in the LapStar. This gives it a large benefit for studying technical skills in transanal procedures.

**V. CONCLUSION**

A training setup was built and relevant metrics were defined capable of showing important differences in technical skills between levels of experience during a transanal purse string suture, a critical step in transanal total mesorectal excision.

**VI. APPENDIX**

Please view the thesis report for a more elaborate description of the project steps.
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