Parallel, Component Training in Robotic Total Mesorectal Excision

Deena Harji MBChB
Bordeaux University Hospital
Nour Aldajani
Bordeaux University Hospital
Thomas Cauvin
Bordeaux University Hospital
Alexander Chauvet
Bordeaux University Hospital
Quentin Denost (quentin.denost@chu-bordeaux.fr)
Bordeaux University Hospital

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Abstract

Background

There has been widespread adoption of robotic total mesorectal excision (TME) for rectal cancer in recent years. There is now increasing interest in training robotic novice surgeons in robotic TME surgery using the principles of component-based learning. The aims of our study were to assess the feasibility of delivering a structured, parallel, component-based, training curriculum to surgical trainees and fellows.

Methods

A prospective pilot study was undertaken between January 2021 and May 2021. A dedicated robotic training pathway was designed with two trainees trained in parallel per each robotic case based on prior experience, training grade and skill set. Component parts of each operation were allocated by the robotic trainer prior to the start of each case. Robotic proficiency was assessed using the Global Evaluative Assessment of Robotic Skills (GEARS) and the EARCS Global Assessment Score (GAS).

Results

Three trainees participated in this pilot study; performing a combined number of 52 TME resections. Key components of all 52 TME operations were performed by the trainees. GEARS scores improved throughout the study, with a mean overall baseline score of 17.3 (95% CI 15.1 – 1.4) compared to an overall final assessment mean score of 23.8 (95% CI 21.6 – 25.9), $p=0.003$. The GAS component improved incrementally for all trainees at each candidate assessment ($p<0.001$).

Conclusion

Employing a parallel, component-based approach to training in robotic TME surgery is safe and feasible and can be used to train multiple trainees of differing grades simultaneously, whilst maintaining high quality clinical outcomes.

Background

The adoption of robotic total mesorectal excision (TME) for rectal cancer has significantly increased worldwide in recent years (1–3). This has been driven through the delivery of standardised robotic training programs for established surgeons leading to rapid skills acquisition (4, 5), whilst maintaining high quality clinical standards. The European Academy of Robotic Colorectal Surgery (EACRS) have demonstrated that through the standardisation of key, component steps in robotic TME, a modular training approach can be appropriately employed (4). Delivery of training in a structured and standardised manner enables reproducibility and mastery of each component step of the operation and lends itself well to training both established consultant surgeons and surgical trainees. As robotic colorectal surgery continues to expand, there is increasing interest and enthusiasm from surgical trainees and fellows to acquire robotic skills during training and in dedicated fellowships (6). However, the development and delivery of formal robotic colorectal surgery training programmes specifically for trainees and fellows on an international scale has been sparse.

The majority of available robotic curricula are aimed at established surgeons and are centred on the principles of competency or proficiency-based training, which benchmarks operative performance using expert validation. This is in contrast to the surgical training model for trainees, which combines time, volume and proficiency-based training, thus following the framework principle of developing expertise which requires deliberate and focused practice (7, 8). A component-based approach to robotic TME surgery training has the potential to focus skills acquisitions on key steps of the operative procedure and to develop gradual expertise during training prior to transitioning to independent practice. The principles of parallel training take this one step further by enabling surgical trainees of differing levels to train in different components of robotic TME surgery during a single procedure, thus improving the overall efficiency of robotic training (9). The aims of our study were to assess the feasibility of delivering a structured, component-based, training curriculum to surgical trainees and fellows. Specifically, our study aims to identify whether trainees of differing training grades and skills sets can dually train on component parts of robotic TME using the principles of parallel learning.

Methods

A prospective pilot study was undertaken between January 2021 and May 2021 to assess the feasibility of delivering a component-based, parallel training curriculum in robotic TME to surgical trainees and fellows. All patients requiring a robotic TME during this timeframe were included. Patients requiring an extended, BeyondTME resection or pelvic exenteration were excluded. Ethical approval was waivered by our institutional board.

Training Structure

The current training structure at CHU Bordeaux consists of an international follow (> 10 years post-graduate training), two French fellows (Chef de Clinique 6–7 years post-graduate) and six residents (1–5 years post-graduate). The International Fellow has completed training and postgraduate exams in their native country and had completed 30 robotic TME resections prior to commencing a dedicated robotic colorectal fellowship. The two Chef de Clinique’s have significant experience of open and laparoscopic colorectal resections, however, were both novice robotic surgeons, with no prior experience. All three have performed greater than 100 colorectal resections in the elective and emergency setting. Every colorectal operation undertaken in Chu de Bordeaux involves three grades of trainees: the International Fellow, a Chef de Clinique, and a resident.

Robotic Training Pathway

A robotic training pathway was designed in November 2020, including online module training, simulator training, dry lab courses and bedside assistance. Following completion of this trainees were able to transition to console operating. Training goals were set following discussion with each trainee prior to the start of the pilot study, with the aim for the International Fellow (Trainee 1) to achieve competence in TME and the Chef de Clinique's (Trainees 2 and 3) to achieve competence in the abdominal aspects of TME surgery.

Console based training was designed based on the recommendations from EACRS and was divided into five component parts: inferior mesenteric artery (IMA) division, inferior mesenteric vein (IMV) ligation, lateral mobilisation, splenic flexure mobilisation and TME. We employed the principles of parallel learning, which involves practising and performing each step until proficiency is obtained (9). This aims to allow refinement and progression through each step within a structured, sequential training programme irrespective of the difficulty of each step, and enables the training of multiple surgeons during one operation (10). Prior to the start of each robotic case the robotic trainer (QD) would allocate component parts of each procedure to the fellow and the trainee based on complexity of each step and previous operative progress. Formal feedback was provided by the robotic trainer intra-operatively, with further formal feedback post-operatively to review performance and identify areas of improvement. Video-based peer-to-peer feedback was undertaken for each operative case to ensure shared learning across all component parts of the operation. A prospectively maintained logbook was maintained to document all key components performed by each trainee. If all parts of the component step were performed by the trainee this was logged as a trainee completed component, if less than fifty percent was completed by the trainee this was logged as a trainer completed component.

All trainees were assessed at the start and end of the pilot study using the Global Evaluative Assessment of Robotic Skills (GEARS) score to assess overall robotic proficiency. This is a validated assessment score, which consists of six domains; depth perception, bimanual dexterity, efficiency, force sensitivity, robotic control and autonomy (11, 12). Each domain is scored on a 5-point Likert Scale, with a total score ranging from 6–30. Higher scores denote better performance. To assess the procedure-specific skills all trainees were assessed at regular intervals throughout the pilot study on completion of 5 cases, using the EARCS Global Assessment Score (GAS) forms. The GAS form consists of contains four modules; (1) robotic docking, (2) colonic dissection, (3) TME and (4) resection and anastomosis. Each component is scored from 1 to 6 (or not applicable if the step is not performed) with the scores given corresponding to the competence levels presented in the GAS form. As demonstrated, the higher the score, the higher the competence level for each component.

Data Collection and Outcome Assessment

Data were collected on patient and operative characteristics. Operative factors recorded included operative time, blood loss and conversion rates. Post-operative outcomes collected included 30-day morbidity, grade of morbidity, hospital length of stay, and 30 day re-operative and readmission rates.

Length of hospital stay was defined as the number of days following the day of surgery until medically fit for discharge. Post-operative complications were classified as adverse events within 30 days of the operation and were classified according to the Clavien-Dindo (CD) classification. The CD classification consists of 5 grades; grade 0 – no complications, grades I-II – minor complications; and grades III – V –

major complications. The highest-ranking complication was recorded for each patient. Re-operative rates were reported as any unplanned re-operation within 30 days of the index operation and re-admission rates were reported as any unplanned admission to hospital within 30 days of the discharge data.

Statistical Analysis

This manuscript was prepared in accordance with guidelines set by the Strengthening the Reporting of Observational Studies in Epidemiology statement (13). Categorical variables were expressed as number and percentage. Continuous variables were expressed as mean and standard deviation. The independent student t-test was used to examine differences in mean scores in two groups and the one-way analysis of variance (ANOVA) for more than two groups. All analyses were conducted using IBM SPSS Statistics version 26.0.0.1 for Macintosh (IBM Corp., Armonk, New York, USA).

Results

Fifty-two patients underwent TME surgery during the study period, with 40 (76.9%) male patients with a median age of 67 included. The majority of tumours were located within the middle or lower third of the rectum, with an average median distance of the tumour from the anal verge of 8cm (IQR 6–10). Patient and tumour characteristics are highlighted in Table 1.

Table 1
Patient and Tumour Characteristics

Variable	Number
Gender	
Male	40 (76.9)
Female	12 (23.1)
Median Age	67
ASA	
I	14 (26.9)
II	30 (57.6)
III	8 (15.3)
Tumour location	
High rectal	6 (11.5)
Mid rectal	30 (57.6)
Low rectal	16 (30.7)
Neoadjuvant Treatment	
Chemoradiation	31 (59.6)
Chemotherapy	10 (19.2)
None	11 (21.1)
Radiological T Stage	
T2	6 (11.5)
T3	34 (65.3)
T4	12 (23.0)
Radiological N Stage	
N0	17 (32.6)
N1	26 (50.0)
N2	9 (17.3)

Variable	Number
Radiological Margin Status	
Negative	20 (38.4)
Positive	21 (40.3)
Threatened	11 (21.1)

Key components of all 52 TME operations were performed by all trainees (Table 2). The trainees performed a higher proportion of IMA division compared to the fellow; with rates of 88.4% vs 5.8%, $p < 0.001$. A similar proportion of IMV ligation were performed by both training grades, with the trainees performing 36.6% (n = 19) and the fellow performing 34.6% (n = 18), p = 0.56. The fellow performed the majority of the TME (n = 47, 90.4%). Overall, the robotic trainer completed the following component steps; 3 (5.8%) IMA division, 15 (28.8) IMV ligation, 14 (26.9%) lateral mobilisation, 2 (3.8%) splenic flexure mobilisations and 5 (9.6%) TME.

Table 2
Robotic Training Components

	Training Component				
Operating Surgeon	**IMA Division**	**IMV Ligation**	**Lateral Mobilisation**	**Splenic Flexure Mobilisation***	**TME**
Trainee 1	3 (5.8)	18 (34.6)	5 (9.6)	19 (36.5)	47 (90.4)
Trainee 2	27 (51.9)	11 (21.2)	28 (53.8)	9 (26.4)	-
Trainee 3	19 (36.5)	8 (15.4)	5 (9.6)	4 (11.7)	-
Robotic Trainer	3 (5.8)	15 (28.8)	14 (26.9)	2 (3.8)	5 (9.6)
*** Splenic flexure mobilisation in 34 patients alone.**					

Clinical outcomes are outlined in Table 3. The overall median operating time was 276 minutes (IQR 230–302), with an overall blood loss of 100mls (IQR 0–200). The conversation rate to open surgery was 1.9% (n = 1) due to a difficult splenic flexure mobilisation. There were no intra-operative complications. Our overall rate of post-operative complications was 21.1% (n = 11), with a median length of stay of 7 (IQR 5–11) days. Our rate of margin positivity was 3.8% (n = 2).

Table 3
Clinical outcomes

Operative Outcomes	Number (%)
Operating Time (mins)	276 (230–302)
Blood Loss (mls)	100 (0-200)
Conversion rate	1 (1.9%)
Intra-operative complication rate	0 (0.0)
Post-operative complication rate	11 (21.1)
Clavien-Dindo Classification	
0	7 (13.5)
I-II	37 (71.1)
III-IV	8 (15.3)
Tumour margin status	
R0	50 (96.1)
R1	2 (3.8)
Median Length of Stay	7 (5–11)
30-day re-admission rate	2 (3.8)

Training Assessment

All trainees made significant improvements across all domains of the GEARS score throughout the study, with a mean overall baseline score of 17.3 (95% CI 15.1–21.4) compared to an overall mean score of 23.8 (95% CI 21.6–25.9), $p = 0.003$ (Table 4, Fig. 1). The GAS component scores improved incrementally for all trainees at each candidate assessment ($p < 0.001$) (Fig. 2).

Table 4
GEARS Scores

Trainee	Overall Baseline GEARS Score	Overall Final GEARS Score	P Value
Trainee 1	23	29	0.003
Trainee 2	18	24	
Trainee 3	15	22	

Discussion

Our study highlights a novel manner in training multiple trainees simultaneously with differing ability and skillset in robotic rectal cancer surgery, whilst maintaining high-quality clinical and oncological outcomes. Employing a component-based approach to robotic TME enables the timely acquisition of key robotic skills including depth perception, bimanual dexterity, efficiency, force sensitivity and robotic control, whilst developing proficiency in core components of complex TME surgery. This is reflected in the significant improvements in overall GEARS scores ($p = 0.003$) and component GAS scores ($p < 0.001$) observed for all trainees in our study.

Robotic colorectal surgery lends itself well to employing a component approach, with several expert robotic trainers acknowledging the merits of this approach. Using a component-based approach based on key operative steps to robotic TME, the EACRS robotic programme was able to demonstrate robotic proficiency amongst established and trainee colorectal surgeons (4, 5, 14). In contrast, Castaldi et al have developed the RAST (Robotic-Assisted Surgical Training) programme which is based on three key modules to develop proficiency in robotic ergonomics, psychomotor skills and procedural skills, increasing in complexity of skills acquisition in a stepwise fashion, for surgical residents and trainees (15). Although our curriculum is based on the EACRS' curriculum with regards to its component operative steps, the novelty of our approach is training two trainees simultaneously during one procedure, thus employing the principles of parallel learning. This approach introduces efficiency into the robotic training pathway, enables efficient acquisition and development of operative skills in a stepwise fashion, promotes sequential learning and enables safe operative progression of a complex procedure. This is of particular importance and value when training is delivered with limited case volume during a defined time period (16). The principles of parallel, component-based learning have been implemented and championed in robotic urology (9), with Dev et al demonstrating accelerated robotic proficiency and efficiency of developing a critical mass of trained robotic surgeons using this approach (10). Employing this in colorectal surgery has the potential to accelerate robotic training and enables the timely development of a critical mass of robotically trained colorectal surgeons.

Recent international benchmarks for robotic surgery for low anterior resection provides a framework of key clinical standards, including cut off values for conversion of < 4.0%, intra-operative complication rates of < 1.4% and < 28% for all post-operative complications (17). Our clinical outcomes fall within the remit of these international benchmarking criteria, despite all operations being performed by trainees. It is important to acknowledge that these benchmarking criteria are for established colorectal surgeons, and that currently, there are no well-defined benchmarking criteria for robotic surgical trainees (18). Despite this, the results from our study suggest that well-developed, high quality robotic training programmes can deliver and maintain high quality clinical outcomes in keeping with international standards. Our results are supported by the works of Waters et al, who demonstrated equivalent clinical and oncological outcomes between established robotic surgeons and robotic fellows within the context of a dedicated robotic fellowship (19). Furthermore, our results are also comparable to other published experience reflecting the initial learning curve in robotic TME surgery, with both our median operating time (276 minutes) and intra-operative conversion rate of 1.9% in keeping with published operating times of 354–510 minutes and conversation rates of 1.1–2.2% (14, 20–23). This supports the notion that parallel component robotic training has no adverse impact on intra-operative parameters such as operating time and post-operative clinical outcomes, and therefore represents a resourceful and efficient manner of robotic training.

Employing objective assessment measures to assess competency is essential in safeguarding clinical standards in robotic colorectal surgery. We employed the GEARS score to assess overall robotic competency and the GAS score to assess procedure-specific competency. The GEARS outcome assessment measure has been robustly validated and is able to adequately discriminate between surgeons with differing skills level and expertise (11, 12, 24). In contrast, the GAS score was created to provide objective evaluation for surgeons participating in the EACRS training programme, without comprehensive validation. Therefore, the validity of the GAS score is questionable as its measurement properties have not undergone robust evaluation, however, despite this it is the only available procedure-specific objective assessment measure available for robotic TME surgery. We adopted these outcome measures due to their widespread popularity and ease of use, however, we acknowledge the limitations of these assessment measures, which includes, measurement error and assessor bias. Alternative ways of assessing robotic proficiency include using cumulative sum analysis (CUSUM) learning curves, however, we felt using this approach would be difficult in assessing and attributing individual robotic component proficiency with regards to operative and clinical outcomes. The use of objective performance indicators derived directly from the robotic system, reporting kinematic and event data, will provide the most objective assessment of technical proficiency in robotic surgery (25). These automated performance metrics will provide accurate and timely assessment data, which will transform the assessment of robotic competency as the utility of these metrics becomes more widespread.

The key strength of our work is the using a standardised and well-developed robotic curriculum and modifying this to incorporate parallel training whilst considering individual training grades and objectives, thus enabling the training of multiple trainees simultaneously. The efficiency of this approach is demonstrated through the acquisition of overall robotic and procedure specific skills using objective assessment measures and the progression through key components of TME surgery. Parallel, component robotic learning enables mastery of each individual step, irrespective of the difficulty of the operative procedure, thus building robotic skills in a novel and efficient manner. The main limitation of our pilot study is that trainees did not progress to completing an individual case from start to finish and therefore the overall robotic proficiency of this approach remains untested. However, the aims of our work were to demonstrate whether using the principles of parallel training were feasible for robotic TME. It is important to acknowledge that this training programme was delivered within the context of a well-developed and mature robotic colorectal unit and an experienced robotic trainer. Future works will focus on the progression from parallel component training to overall procedural completion and the impact of training in this manner on operative and clinical outcomes. Furthermore, future incorporation of kinematic and event data with clinical outcomes will provide more robust evaluation of this approach. Acknowledging the role of trainee teamwork, the wider robotic team and technical robotic skills is important and requires further consideration in the delivery of parallel, component training.

Conclusions

Employing a parallel, component-based approach to training in robotic TME surgery is safe and feasible and can be used to train multiple trainees of differing grades simultaneously, whilst maintaining high quality clinical outcomes.

Declarations

Competing Interests

Miss Deena Harji wass a European Society of Coloproctology/Intuitive Robotic Surgery fellow in 2020/21 and Professor Quentin Denost is a current European Society of Coloproctology/Intuitive Robotic Surgery Trainer. Drs Nour Aldajani, Thomas Cauvin and Alexander Chauvet have no conflicts of interest or financial ties to disclose.

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Drs Nour Aldajani, Thomas Cauvin and Alexander Chauvet. The first draft of the manuscript was written by Miss Deena Harji and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.”

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Figures

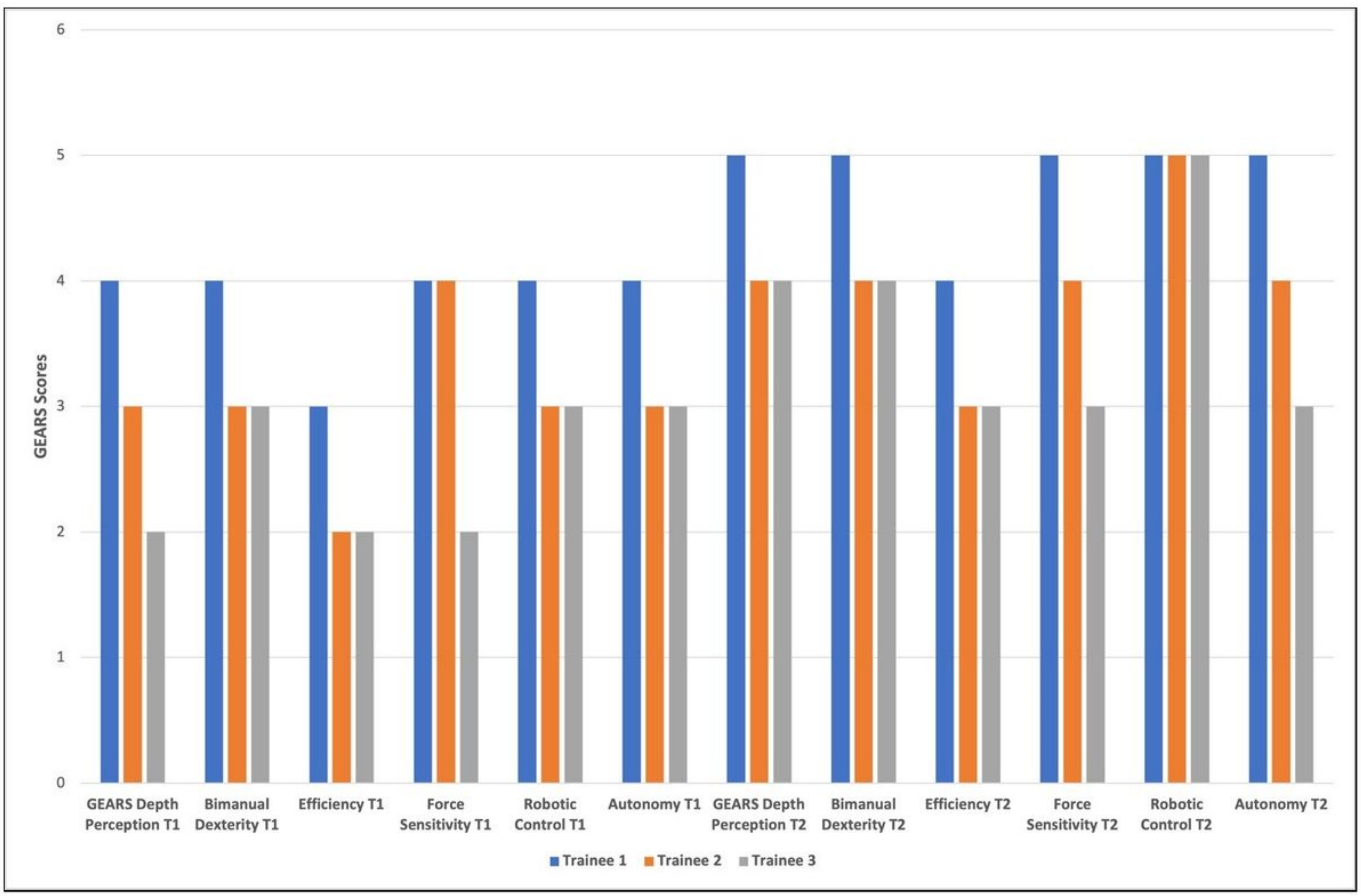

Figure 1

GEARS Domain Level Scores

*T1 = Baseline assessment, T2 = Final assessment

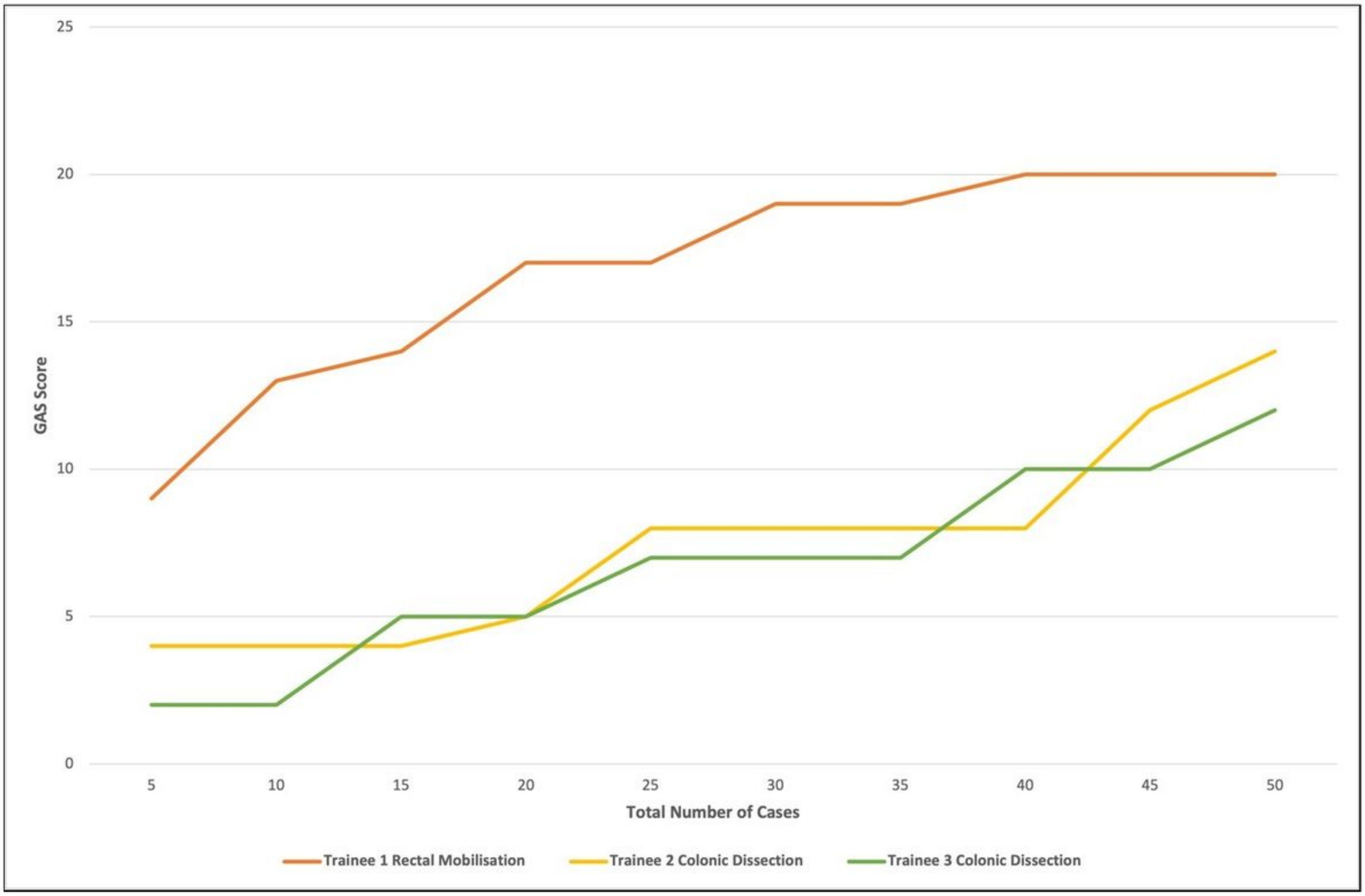

Figure 2

Component GAS Scores