Reducing healthcare delivery costs using Augmented Reality based Surgical Simulation: A Health Economics Study

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Introduction

Surgical training traditionally was learned by trainee surgeons through repeated practice on patients. This process can be time consuming, costly and have variable effectiveness(1). Consequently, the use of virtual reality and simulations have become an option to supplement standard training. In 2009 a Cochrane review found evidence that virtual reality can improve training against standard surgical training. The trials included in the review reported decreased time to complete a task, increased accuracy, and decreased errors(2).

With technology advances, simulation has become a common approach to substitute clinical experiences in the early learning curve of trainee surgeons. However, simulation based education is not without an expense and the costs involved with traditional Virtual Reality based simulation remains unreported and incomplete(3). Zendjas 2013 report that costs are often the missing outcome when evaluating technology simulations and are rarely compared among alternatives. The Objective Structured Clinical Examination (OSCE) cost around £325 per student (4). As a competing approach to a certain extent, it is relevant to understand the costs and consequences of competing approaches given limited resources to implement them.

This report will seek to assess the potential return on investment for a novel, Augmented Reality (AR) based surgical simulation platform used to deliver surgical training and education. The report will focus on the potential economic benefits the platform could deliver across a single National Health System.

Potential Financial Impact

Needham et al estimated the costs of a laparoscopic appendectomy in 2007 8. In combining this data with the PSSRU hospital & HCHS community health services index, and total hospital stay 9,10, we estimated in Table 1 that the potential cost savings per patient would be £79. If we were to assume 150 acute trusts 11 are undertaking 10,000 laparoscopic appendectomies per day (including fixed costs of equipment), the total cost saving would be £777.579 in one particular operation, for one surgical speciality.

The baseline scenario assumes that the Inovus technology will impact the surgical performance of clinicians in terms of the cost of time in theatre for every surgery. However, the likely impact could range from 20-100%.

Consequently, the potential savings where the technology only leads to improvements of efficiency in 20% to 100% of cases is presented.

Table 2 shows that if the surgical performance improves 20% of cases in surgery, the savings per patient will be £16 and the savings realised after the 572nd surgery.

Whilst the savings per patient may not be realised after a certain number of surgeries in the first year, the savings are likely to continue into the subsequent years providing surgical outcomes and techniques are more efficient than the current treatment pathway.

Figure 1: the Inovus LapAR™



Table 1. Potential cost savings per patient with application of new technology

	Current Pathway			New Technology Pathway		
Laparoscopic appendectomy	Number	1,500,000			1,500,000	
Equipment	100%	£299	£448,156,809	100%	£299	£448,500,000
Theatre costs	100%	£780	£1,169,795,136	100%	£702	£1,052,815,623
Ward costs	100%	£776	£1,164,501,946	100%	£776	£1,164,501,946
Medication costs	100%	£48	£72,340,272	100%	£48	£72,340,272
Bowel perforation costs	0.22%	£2,153	£7,104,075	0.20%	£1,937	£5,754,301
Total in-patient costs		£4,056	£2,861,898,238		£3,763	£2,743,912,141
Total in-patient cost per patient			£1,908		£1,829	
Cost difference per patient			£79			

The following assumptions about the impact of the technology is made:
- The introduction of the technology should reduce operative times by 10% i.e. improvement in theatre time/ costs by 10%
- The median total hospital stay will remain the same
- The introduction of the technology should reduce the risk of bowel perforation by 10%
- The cost of treating bowel perforation is £2,152.75 (9)
The improvements in the technology will affect 100% of the patients in the pathway

Table 2. Cost savings per % impact of technology

% impact of the technology	20%	40%	60%	80%	100%
Cost difference per patient	£16	£31	£47	£63	£79
Savings realised after the nth surgery	572	286	191	143	114

In the baseline scenario, the cost difference per patient was estimated on the assumptions of improvement in the efficiency of all surgeries, by 10%, and in the risk of bowel perforations. In a sensitivity analysis, we assumed the efficiency of the surgeries continued to lead to 10% theatre savings, but the risk of bowel perforation remains the same. Given these assumptions, the cost difference per patient to £1 less, than the original saving of £79. When we assumed the efficiency of all surgeries would lead to 5% savings in surgery time, the cost difference per patient reduced to £40 per patient.

Table 3. Sensitivity Analysis

Sensitivity Analysis	Cost difference per patient
Bowel perforation costs remain the same	£78
Theatre costs reduced by 5%	£40

Validation of Efficiency Assumptions

The benefit of the AR training technology is the ability to provide objective metrics through computer vision tracking (powered by a patented machine learning algorithm). The following metrics are recorded throughout any procedure carried out within the platform:
- Completion Time (minutes)
- Distance Travelled / Economy of Movement (metres)
- Smoothness (distance-squared-jerk)
- Acceleration (metres/s)
- Handedness
- Time in view (%)

The two metrics focused on for this paper are Completion Time & Distance Travelled as these are the metrics assumed as having a direct effect on operative time and complications.

A multi-centre study was performed to objectively assess the impact of AR based training on operative time and efficacy, the data is displayed below. The methodology of this study was to provide an Augmented Reality Simulator to each trainee for them to perform a total of 10 appendicectomies with three rounds of 'LapPass®' Tasks(10) interspersed throughout. The intervention period was two weeks and there was a supervised session at the start and at the end of the study which included one round of 'LapPass' and one appendicectomy.

Table 4. Comparison of trainees performance on completion time (minutes) and distance travelled (metres)

Trainee no	Time spent	Max Time	Min Time	Max Distance	Min Distance
1	92	14	5	117	32
2	57	10	4	50	15
3	79	16	4	58	20
4	126	17	6	120	22

Table 4 shows that the technology improves performance in both completion time and distance travelled. The average reduction in time was 9.5 minutes (66% reduction), and the average reduction in distance travelled was 64 metres (72% reduction).

This evidence substantiates the cost savings predicted previously. It shows that a greater than 10% reduction in time to operate can be achieved following the introduction of Augmented Reality based surgical training.

Given that in analysis of the cost savings at 100% impact & 10% efficiency as shown in Table 1, if we were to extrapolate this to 66% efficiency, we would see a potential cost saving of £455 per patient through saved theatre time – leaving a remaining theatre time cost of £325.

Conclusion

Given the technology is designed to improve surgical efficiency at a fixed cost and low maintenance price, there are potential cost benefits that could be achieved. The diagnostic pathway and treatment mix are unlikely to change the Inovus technology has potential to lead to reduction in the overall cost of a laparoscopic appendectomy, provided improvements in efficiency can be successfully translated into cash savings (of theatre time).

In summary, the pandemic has provided us not only with an opportunity to drive the paradigm shift in surgical training to the benefit of our patients' safety, but also to provide a golden opportunity of vast savings to the Kings Fund & beyond. We believe these are just the first steps in a new era of surgical training.

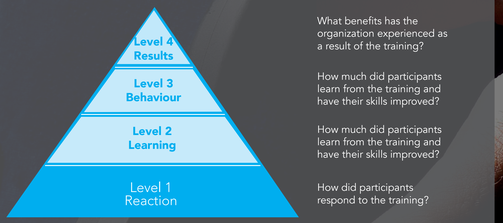


Figure 1. A Kirkpatrick Evaluation Pyramid highlighting outcomes 1 & 2 satisfied through this study.

In a concurrent study, we collected surveys prior to and after: including demographics, prior experience, and self-confidence scores for key laparoscopic tasks on a 1-10 scale, as well as operative skill data using Inovus AR simulation software. Every area of student's self-confidence improved, with a mean improvement of 3.82 (p=0.03). The more junior the student, the greater their increase in confidence (Mean Pre-FY = 5.23)."

Acknowledgements

We are executives with Inovus Medical. In this response we have sought to avoid over-mentioning products or pushing sales. Our intention is to increase awareness of alternative augmented reality training options to drive surgical training away from the patient's bedside. We extend gratitude and thanks to SAGES for allowing us to present our findings.

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