

3D VS. 2D-Imaging in Laparoscopic Procedures: Opportunity Costs Associated with the Reduction of Time in the Operating Room (OR)

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INTRODUCTION

In increasingly competitive environments, time savings in the operating room (OR) are of high relevance for hospitals needing to maximise utilisation of operative capacity. In many public healthcare systems, the demand for time in the OR often outstrips capacity and patients subsequently face long waits for their operations [1].

3D imaging technology or "stereoscopic vision" has gained popularity in laparoscopic surgery in recent years and has been found to significantly reduce OR time in a variety of procedures. In 2018, the European Association of Endoscopic Surgery (EAES) conducted a systematic review and meta-analysis comparing outcomes between 2D and 3D surgery [2]. In their analysis, a pooled result for mean difference in operative time was produced across all included studies, demonstrating a mean reduction of 11 minutes (or 8%) per procedure.

However, there is limited evidence on the value of these time savings to healthcare providers.

OBJECTIVES

Our research assesses the differences in OR time with 3D compared to 2D imaging technology in laparoscopic surgery overall, as well as specifically for a number of procedure types. It further extrapolates the time savings to the casemixes of two real-world hospitals in the UK and Germany and estimates the potential opportunity costs of not switching to a 3D imaging system for the selected procedure types.

METHODS

Literature Review

In July and August 2020, a systematically performed literature review was conducted, searching PubMed for any publications comparing 2D with 3D imaging technology in laparoscopic procedures where operating time was an endpoint. Search terms related to laparoscopic procedures and the compared imaging techniques, resulting in following search strategy: (((("Laparoscopy"[Mh] OR "Laparoscopic" OR "Laparoscopy") AND (3D-laparoscopy OR 3D OR "three-dimensional" OR "3-dimensional laparoscopy" OR "3D-laparoscopic" OR "Imaging, Three-Dimensional"[Mh]) AND (2D-laparoscopy OR 2D OR "two-dimensional" OR "2-dimensional laparoscopy") AND (eng[LA] OR ger[LA]))) AND ("2007"[Date - Publication] : "2020"[Date - Publication])).

Studies in languages other than English and German were excluded, as were studies researching children. Both prospective and retrospective study designs were included, unless they were uncontrolled or did not include the endpoint OR time. Simulation studies, systematic reviews and meta analyses were excluded, but hand-searched for references.

Meta Analysis

A meta analysis was performed using R version 3.4.4. The model used was a random-effects-model for raw effect size data. Differences in OR time between 2D and 3D imaging technology were calculated as mean differences with 95% confidence intervals and percentage change, with tau² and p-values for estimation of heterogeneity. Cochran thresholds were used to interpret tau², p-values <0.1 were considered statistically significant.

Since both, prospective and retrospective studies were included, separate analyses were run for both designs to account for different sample selection methods, which potentially contribute to increased heterogeneity.

Subsequently, the study populations included in the overall result were categorised into subgroups based on the type of procedure performed and analysed, provided there was more than one study population per subgroup. The resulting mean difference in OR time 3D vs. 2D per procedure category served as the foundation of the cost model.

Cost Model

The differences in OR time for each procedure category, provided they were significant, were extrapolated onto casemix data from two public hospitals; Universitätsklinikum Hamburg-Eppendorf (UKE), Hamburg, Germany and Addenbrookes Hospital (Cambridge University Hospitals NHS Foundation Trust), Cambridge, UK. For this, the procedures performed in the studies were mapped to the regional inpatient/admitted patient care OPS/C code system. The reported frequencies of these codes in 2018/19 were retrieved from both hospitals [3, 4] and were used as the basis for the extrapolation of time savings and estimation of opportunity costs.

The modelling of the economic impact was based on different interpretations of the opportunity cost in each of the three following scenarios:

Scenario 1: Several publications assessed the value of OR time in different countries, primarily on the basis of a combination of staff and facility costs. The first interpretation of opportunity cost is that 100% of the time savings in the OR could be used to close the OR earlier and stop incurring these costs. Underlying reference values are 9.45€ (95%CI 8.60-10.23€) per minute in the OR for UKE [5] and £16.48 per minute in the OR for Addenbrookes Hospital [6].

Scenario 2: The second interpretation of the opportunity cost of OR time savings is that 100% of the saved time can be used to perform procedures additional to the current casemix. For this scenario, the total time savings were used to proportionally expand the baseline casemix.

Scenario 3: Acknowledging that both of the scenarios outlined above may be quite extreme in that they use 100% of the time savings to either close the OR early or to perform additional procedures, regardless of staff and facility constraints, the third interpretation aims at depicting a mix of the two. Hence, a split between both scenarios is being presented, assuming 60% of the time savings are used to perform additional procedures, and 40% are used to close the OR early (or at least on time).

Where we have estimated the additional revenue each hospital could earn by performing additional procedures, an average reimbursement was determined for each procedure category, based on the mapped inpatient/admitted patient care OPS/C code(s). Where there was more than one code per category, reimbursement was weighted based on national usage data, NHS Hospital Episode Statistics Data in England and G-DRG Browser 2019.1 in Germany.

RESULTS

Literature Review & Time Savings

A total of 338 records were found in the literature review. After removal of duplicates and initial screening phase, 86 full-text articles were assessed for eligibility. Of these, 34 were excluded, mostly based on methodology or study design. A total of 70 study populations, taken from 52 studies, were analysed in the meta-analysis.

Overall, the mean difference in OR time using 3D vs. 2D was -19.36 [95%CI -24.27;-14.45] minutes per procedure (-14%, I² 92%, p<0.01) in favour of 3D.

Separate analyses for prospective and retrospective study designs revealed no major improvements regarding heterogeneity, but differences in overall OR time. Looking at studies with prospective design only, the overall time difference with 3D vs. 2D in prospective studies only was -15.52 [95%CI -21.91; -9.13] minutes (I² 89%, p<0.01) in favour of 3D, compared to -23.25 [95%CI -30.59; -15.90] minutes (I² 92%, p<0.01) in retrospective studies.

During the procedure type subgroup analysis, there were seven cases in which there was only one study population of the respective type of procedure. These study populations were not considered in the subgroup analysis.

Table 1. Meta analysis results on the differences in OR time with 3D vs. 2D imaging technology in selected laparoscopic procedures

Treatment Category	n		Time per procedure (min)		Mean difference 3D vs. 2D (min)	95% CI	Mean difference 3D vs. 2D (%)	Heterogeneity		References
	3D	2D	3D	2D				I ²	p-value	
Adrenalectomy	141	115	86.16	108.70	-22.56	[-35.6 ; -9.51]	-21%	58%	0.07	[7], [8], [38], [45]
Cholecystectomy	196	243	35.66	49.31	-13.64	[-25.37 ; -1.91]	-28%	93%	<0.01	[13], [20], [47], [56]
Distal Gastrectomy	164	177	240.20	281.85	-41.66	[-69.72 ; -13.61]	-15%	95%	<0.01	[25], [26], [31]
Inguinal Hernia Repair (TAPP)	53	44	44.50	68.45	-23.96	[-56.34 ; 8.42]	-35%	83%	0.01	[24], [41]
Liver Resection Procedures	50	85	319.91	358.52	-38.61	[-69.73 ; -7.49]	-11%	0%	0.35	[27], [53]
Living Donor Nephrectomy	57	138	89.66	109.95	-20.31	[-44.44 ; -3.82]	-18%	94%	<0.01	[42], [54]
Mixed Colorectal Resection	104	115	154.73	177.11	-22.4	[-53.18 ; 8.38]	-13%	95%	<0.01	[8], [49], [57]
Partial Nephrectomy	76	89	111.18	115.21	-4.06	[-23.59 ; 15.47]	-4%	45%	0.14	[29], [38], [46], [30]
Pyeloplasty	34	31	120.81	158.85	-38.04	[-59.41 ; -16.67]	-24%	0%	0.86	[38], [40]
Radical Hysterectomy	160	180	111.12	143.58	-32.44	[-48.64 ; -16.25]	-23%	30%	0.23	[8], [22], [23], [44]
Radical Nephrectomy	38	41	157.14	184.50	-27.37	[-48.47 ; -6.27]	-15%	0%	0.93	[8], [38], [40]
Radical Prostatectomy	188	226	127.98	158.40	-30.44	[-63.58 ; 2.7]	-19%	97%	<0.01	[10], [11], [16], [28], [30]
Right Hemicolectomy	105	109	117.86	131.31	-13.46	[-25.1 ; -1.81]	-10%	72%	0.03	[17], [21], [51]
Roux-en-Y Gastric Bypass	93	194	170.71	205.60	-34.88	[-46.79 ; -22.97]	-17%	0%	0.83	[37], [39]
Simple Nephrectomy	31	36	73.54	91.08	-17.56	[-58.73 ; 23.61]	-19%	84%	0.01	[30], [40]
Sleeve Gastrectomy	54	102	81.79	94.56	-12.77	[-31.76 ; 6.22]	-14%	80%	0.02	[19], [39]
Total Gastrectomy	457	463	178.61	179.78	-1.17	[-7.82 ; 5.48]	-1%	19%	0.29	[33], [34], [35], [58]
Total Laparoscopic Hysterectomy	462	556	101.17	118.37	-17.18	[-26.51 ; -7.85]	-15%	0%	0.44	[9], [12], [48], [52], [55]

The subgroup analysis resulted in 18 different procedure types with varying magnitudes of OR time differences. Not all results in the subgroup analysis were significant however. Ten of the 18 subgroups showed a significant time reduction in favour of 3D, whereas eight did not. Of the significant results, the greatest absolute differences were seen in Distal Gastrectomy (-41.66min [95%CI -69.72; -13.61]) and Liver Resection Procedures (-38.61min [95%CI -69.73; -7.49]). The greatest statistically significant difference in OR time relative to the mean procedure time with 2D was seen in Cholecystectomy (-25.37min [95%CI -25.37; -1.91] -28%, I² 93%, p<0.01). In one subgroup, Total Gastrectomy, almost no reduction in OR time was seen (-1.17 min [95%CI -7.82; 5.48]); however this result was not statistically significant. A full breakdown of the results can be seen in Table 1 [7-58].

Extrapolation of the significant results from the procedure type subgroup analysis to the two sample casemixes resulted in total OR time savings of 1.33 [95%CI 0.44; 2.22] hours per working day for UKE and 1.62 [95%CI 0.42; 2.82] hours per working day for Addenbrookes Hospital.

Economic Impact

Using our three scenarios for different ways of interpreting the potential opportunity costs of the time savings, the above results can be used to project the following economic impact for our two sample hospitals:

Scenario 1 – Assumption: 100% of time savings attributed to OR cost savings

The economic impact in scenario one was a reduction in cost of €189,017.39 [95%CI €57,344.46; €341,034.95] per year at UKE and £400,188.12 [95%CI £103,180.29; £697,176.35] per year at Addenbrookes Hospital.

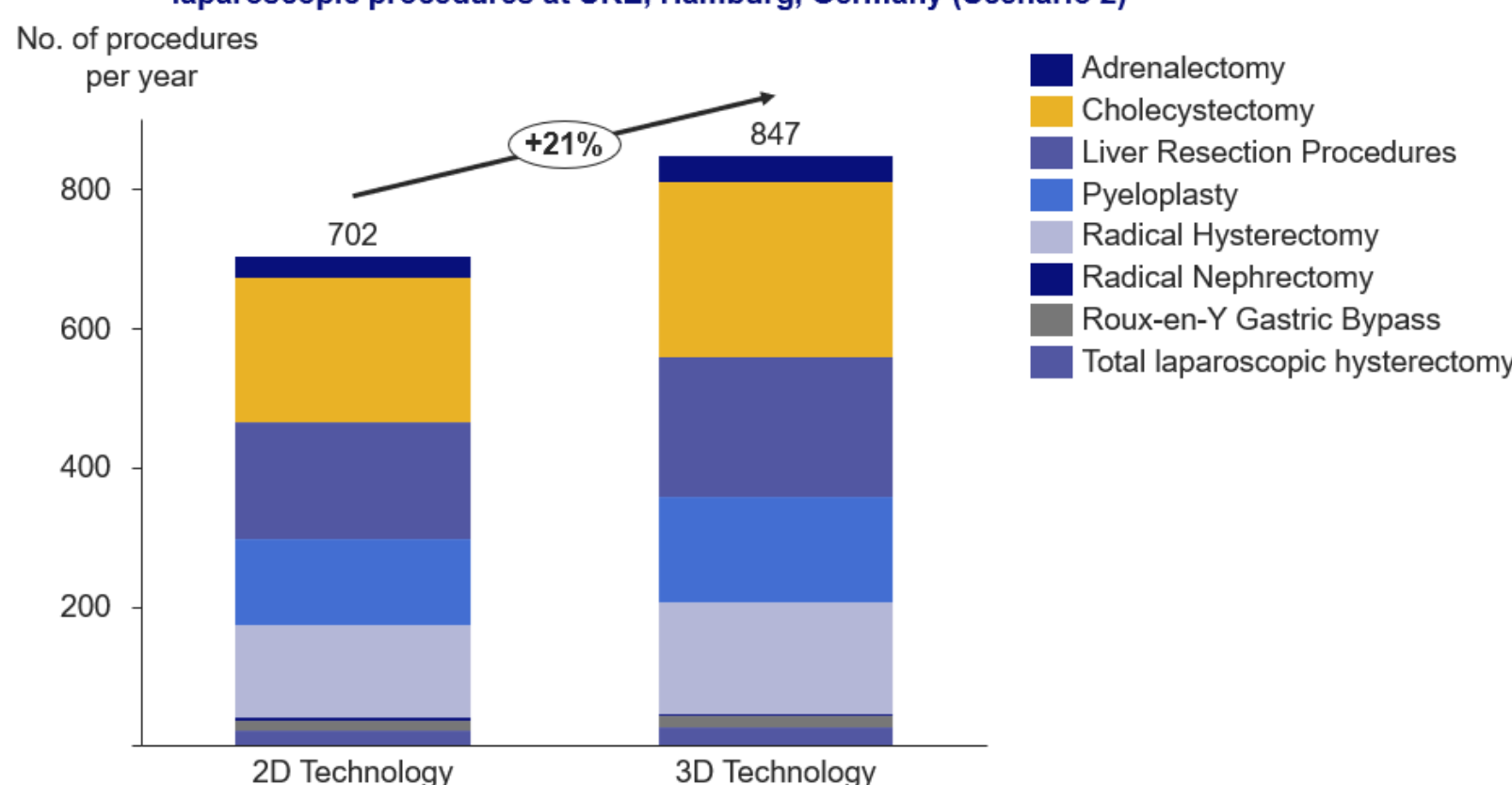
Scenario 2 – Assumption: 100% of time savings attributed to additional procedure revenue

The economic impact in scenario two was an increase in revenue of €887,161.82 per year at UKE, equivalent to a casemix increase of 21%. The projected increase in casemix for UKE is displayed in Figure 1. At Addenbrookes Hospital, the economic impact was an increase in revenue of £690,207.04 per year, equivalent to a casemix increase of 19%.

Scenario 3 – Assumption: 40% of time savings attributed to OR cost savings and 60% attributed to additional procedure revenue

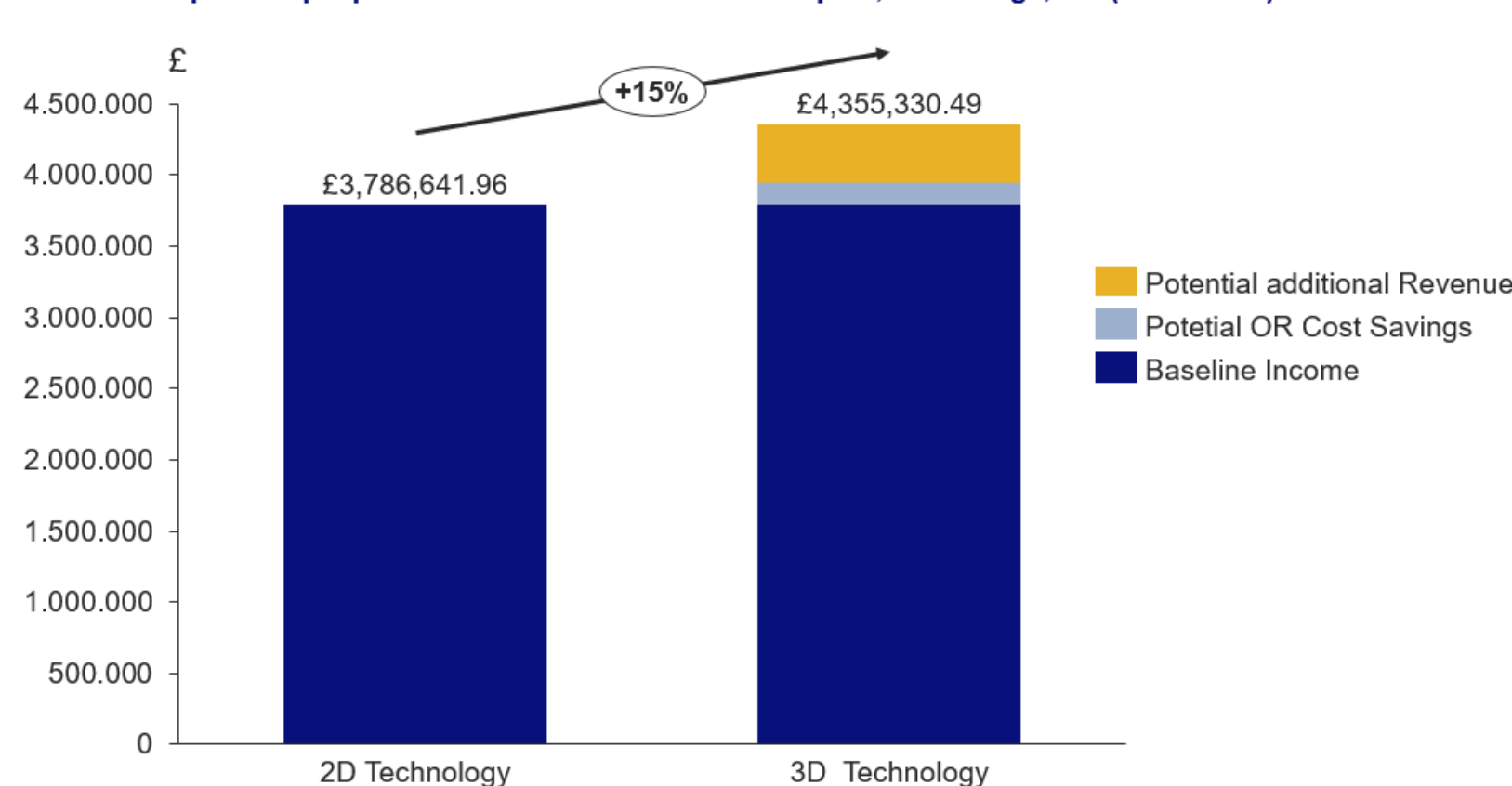
The combined economic impact in scenario three was €603,289.96 per year at UKE, comprising of €75,606.96 in reduced costs as well as €527,683.00 in additional revenue. At Addenbrookes Hospital, the economic impact in this scenario was £568,688.53 per year, comprising of £160,075.25 in reduced costs and £408,613.28 in additional revenue. The combined economic impact at Addenbrookes in scenario three is displayed in Figure 2.

Figure 1. Economic impact simulation of 3D vs. 2D imaging technology for selected laparoscopic procedures at UKE, Hamburg, Germany (Scenario 2)*



*Based on 2019 Quality Report data [3]; Assuming 100% of time savings are used to perform additional procedures, proportionally to the baseline casemix; Subject to staff and facility constraints as well as baseline procedures being performed with 2D.

Figure 2. Economic impact simulation of 3D vs. 2D imaging technology for selected laparoscopic procedures at Addenbrookes Hospital, Cambridge, UK (Scenario 3)*



*Based on 2018/19 HES data [4]; Assuming 60% of overall time savings are used to perform additional procedures, proportionally to the baseline casemix and 40% are used to close the OR early, thereby saving staff & facility costs [6]; Subject to staff and facility constraints as well as baseline procedures being performed with 2D.

DISCUSSION

Our research demonstrates the potential of 3D imaging technology to reduce OR time in laparoscopic procedures by, on average, -19.36 [95%CI -24.27;-14.45] minutes per procedure, which is equivalent to 21% of the average procedure time with standard 2D imaging technology. It supports the outcomes of the EAES consensus meeting in 2017, suggesting that 3D can help hospitals to optimise utilisation of OR time, which, in turn, may help to reduce long surgical waiting lists.

In addition to the updated quantification of the potential reductions in OR time, our study has added the evaluation of the economic impact of time savings in different scenarios. To our knowledge, this is the first economic interpretation and application of OR time savings associated with 3D laparoscopy onto real-world hospital casemixes.

As with the EAES paper, heterogeneity for the overall mean reduction in OR time was high (I² 92%). Our approach to reduce heterogeneity was to analyse subgroups per procedure type. Unfortunately, this was not successful in all subgroups. Other limitations of our results are the search strategy and method, having included records from PubMed only and not having performed a full qualitative assessment of risk of bias of the individual records. Furthermore, scenarios two and three are subject to the assumption that the hospitals have sufficient ward bed and staffing resources to complete the additional procedures, which may not always be the case in reality. Lastly, the two hospital scenarios assume that all procedures are currently performed with 2D technology, which may not be the case as we did not consult with the hospitals.

Strikingly, our overall result demonstrates time reductions with 3D compared to 2D 76% greater than that of the EAES paper. This can potentially be explained by the inclusion of studies with retrospective design, which generally showed greater reductions in OR time than those with prospective design. At the same time, the procedure types researched with both study designs were vastly different, mitigating this hypothesis. Another explanation for the greater time reductions could be the 3D imaging technology itself, which may have improved in recent years, subsequently enabling surgeons to perform surgery even faster than before.

With our research, we provide different alternatives for the interpretation of OR time savings into opportunity costs. Future research is required to find the approach that is the most meaningful in current clinical practice and also considers other cost factors, i.e. the cost of the technology itself, in order to comprehensively assess the cost-effectiveness of 3D vs. 2D imaging technology in laparoscopic procedures.

DISCLOSURES

Authors of this paper are employees of Olympus Europa and UKIE

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