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Financial modelling of femtosecond laser-assisted cataract surgery within the National Health Service using a 'hub and spoke' model for the delivery of high-volume cataract surgery

H W Roberts,[1,2] M Z Ni,[3] D P S O'Brart[1,2]

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[1]Department of Ophthalmology, Guy's and St Thomas' NHS Foundation Trust, London, UK
[2]King's College London, London, UK
[3]Division of Surgery, Department of Surgery and Cancer, Imperial College London, St Mary's Hospital, London, UK

Correspondence to
Professor D P S O'Brart; davidobrart@aol.com

ABSTRACT

Aims: To develop financial models which offset additional costs associated with femtosecond laser (FL)-assisted cataract surgery (FLACS) against improvements in productivity and to determine important factors relating to its implementation into the National Health Service (NHS).

Methods: FL platforms are expensive, in initial purchase and running costs. The additional costs associated with FL technology might be offset by an increase in surgical efficiency. Using a 'hub and spoke' model to provide high-volume cataract surgery, we designed a financial model, comparing FLACS against conventional phacoemulsification surgery (CPS). The model was populated with averaged financial data from 4 NHS foundation trusts and 4 commercial organisations manufacturing FL platforms. We tested our model with sensitivity and threshold analyses to allow for variations or uncertainties.

Results: The averaged weekly workload for cataract surgery using our hub and spoke model required either 8 or 5.4 theatre sessions with CPS or FLACS, respectively. Despite reduced theatre utilisation, CPS (average £433/case) was still found to be 8.7% cheaper than FLACS (average £502/case). The greatest associated cost of FLACS was the patient interface (PI) (average £135/case). Sensitivity analyses demonstrated that FLACS could be less expensive than CPS, but only if increased efficiency, in terms of cataract procedures per theatre list, increased by over 100%, or if the cost of the PI was reduced by almost 70%.

Conclusions: The financial viability of FLACS within the NHS is currently precluded by the cost of the PI and the lack of knowledge regarding any gains in operational efficiency.

Strengths and limitations of this study

- Data were collected and collated from four NHS foundation trusts of various sizes, locations and demographics to ensure the conclusions could be more representative.
- This is the only study investigating the financial implications of femtosecond laser-assisted cataract surgery (FLACS) which highlights the significance of the cost of the disposable patient interfaces over the capital cost of the laser machine itself.
- This is the only study investigating the financial implications of FLACS which has developed a working model incorporating a laser to improve, rather than impede productivity.
- This study falls short of providing an incremental cost-effectiveness ratio for FLACS. For the purposes of this model, clinical outcomes are assumed to be equivalent. This is currently supported by the latest evidence.

INTRODUCTION

In 2014–2015, over 370 000 cataract operations were performed on the National Health Service (NHS).[1] This was 3.7 times the number performed in 1989.[2] The need for cataract surgery is expected to rise further with increasing life expectancy, rising population size, growing patient expectations and an increase in age-related chronic diseases associated with cataracts, such as diabetes.[3] With current financial constraints, this increased future demand for cataract surgery within the NHS is liable to be problematic.

Femtosecond laser (FL) technology has been recently introduced into cataract surgery in an attempt to automate and improve the efficacy and safety of some of the surgical steps within this procedure.[4] Within the scientific literature, there are now numerous prospective case series supporting its usage and continued development and more surgeons are adopting this new technology.[4–9] However, while FL technology undoubtedly offers great surgical precision, a

recent meta-analysis shows no significant advantages in terms of safety and efficacy of FL-assisted cataract surgery (FLACS) over conventional phacoemulsification cataract surgery (CPS).[10] Two large multicentre randomised controlled trials (RCTs) are currently underway in France and the UK and may provide further evidence as to whether there is a difference in the clinical outcomes from FLACS.[11 12]

Until evidence exists of improved surgical outcomes, it is difficult at present to support the widespread implementation of FLACS. This is particularly pertinent as the introduction of FLACS has significant associated financial costs. These include initial purchase costs of the FL system itself, servicing, depreciation and the individual patient interfaces (PI), which call into question its financial viability, especially in a state-funded healthcare system. The majority of existing literature on the economics of FLACS originates from healthcare systems within countries such as the USA or Australia, where additional costs from procedures perceived as having a premium status may be passed onto the patient in the form of a copayment system.[13–15] In these healthcare systems, the existing literature suggests that FLACS is not, at this time, a cost-effective solution. It is not surprising, therefore, that adoption of this technology within the NHS so far has been minimal and largely directed at research rather than service provision.

Despite associated costs, by its very nature, the FL offers the potential to remove several steps of cataract extraction from needing to be performed by a fully trained surgeon in a fully equipped ophthalmic operating theatre. FL technology can automate several surgical steps of the cataract procedure, such as corneal incisions, arcuate keratotomies, capsulotomy and nuclear lens division, all of which can be potentially undertaken with this technology by a doctor in training or suitably trained nurse or technician in a clean room. By reducing the actual amount of time each patient spends within the operating theatre under the care of a trained surgeon, the volume of surgical cases undertaken in a given period of time might potentially be increased. This may be especially true if a 'hub and spoke' model is utilised, with the FL performing these initial automated steps and then allowing the completion of the surgical procedure to be undertaken in more than one operating theatre at a time. If the number of cases per theatre session can be increased sufficiently then the initial expenditure and additional costs associated with FL technology might be offset.

For FLACS to see increased adoption by a state-funded healthcare system such as the NHS, it would need to be shown to be cost-effective based on an acceptable incremental cost-effectiveness ratio (ICER). The ICER is defined by the difference in the cost between two possible interventions divided by the difference in their clinical effectiveness. This study aims to investigate, in the absence of clinical outcomes from large RCTs showing any surgical benefit, the cost of incorporating FLACS into the NHS system in order to determine whether the increased costs of equipment may be offset by an increase in the volume of surgery performed.

METHODS
Financial model
A financial model was designed to compare FLACS against CPS for the provision of cataract surgery within the NHS. The inputs for this model can be seen in table 1. The model was based on data from four separate NHS Foundation Trust Ophthalmology Departments (Guy's and St Thomas' NHS Foundation Trust, Norfolk and Norwich NHS Foundation Trust, Peterborough and Stamford NHS Foundation Trust and West Suffolk NHS Foundation Trust) and four manufacturers of commercially available FL devices (Abbott Medical Optics, Santa Ana, California, USA; Ziemer Ophthalmic Systems AG, Switzerland; Alcon Laboratories, Fort Worth, Texas, USA and Bausch & Lomb, Rochester, New York, USA). The data were collated and averaged to ensure the results were more representative than had just one ophthalmology department or one FL been used.

Values for each input were derived from the following sources.
1. Income for each procedure is reimbursed at the NHS national tariffs for 2014–2015 plus an additional market forces factor.[16 17]
2. Costs were divided into direct labour costs, equipment costs and overheads. Direct labour costs per theatre session were derived from NHS pay scales and midpoint values were chosen. This was then proportioned to the estimated duration of each theatre session.
3. Costs relating to the FL were averaged from those provided by four manufacturers of commercially available FL devices.
4. Costs such as estate, equipment and supplies were averaged from four NHS Foundation Trusts' departmental budgets (2014–2015).
5. Pharmacy and administrative costs were obtained by reviewing the departmental budget at our institution.
6. Baseline values for the number of cases achievable per 4-hour theatre session were given nominal values of 7 cases for CPS and 10 cases for FLACS. These initial values were then tested using sensitivity and threshold analyses.

The model was tested based on two scenarios: FLACS versus CPS based on an average number of seven cases currently performed on a CPS cataract lists and a FLACS delivery model based on a 'hub and spoke' method with one FL in a clean room and operated by a doctor in training preparing patients for two operating theatres running in parallel with their associated surgeons, nursing and technical support staff.

'Hub and spoke' FLACS model
Our theoretical 'hub and spoke' model for FLACS is based on a single FL platform in a clean room and

operated by an ophthalmology registrar or suitably trained allied health professional and supported by a theatre nurse (figure 1). The laser would be programmed to perform capsulotomy, nuclear lens division and arcuate keratotomies (when indicated) for each individual patient. Patients would be prepared for two operating theatres running in parallel with their associated surgeons, nursing and technical support staff. The assumed FL treatment time is a maximum of 10 min per patient allowing for the preparation of up to 20 cataract surgery cases, 10 per theatre per 4-hour operating theatre session. The assumed theatre time is a

Table 1 Inputs for the model and nominal values

Source		Input	Value (£)	Range (£)
A				
Income		NHS tariff for cataract surgery	789	729–917
Expenses	Staffing (per session)	Consultant surgeon	246	
		Band 5 nurse	79	
		Registrar/laser technician	101	
		Band 6 nurse/laser technician	102	
		Ward clerk	53	
	Overheads (per year)	Ophthalmic day-case unit	525 620	30 112–1 061 481
		2× operating theatres	585 676	353 245–962 287
	Laser	Initial cost	262 500	175k–350k
		Maintenance/year	28 333	20k–35k
		Cost of patient interface	134.75	99–170
	Other costs	Disposables and IOL (per case)	103	
		Cost of administration, management and pharmacy (per case)	50	
B				
Other variables		Number of cataract operations required per week	55 operations	27–96
		Number of cases on CPS list	7 operations	
		Number of cases on FLACS list*	10 operations	
		Lifetime of FL	10 years	

*Based on the hub and spoke FLACS delivery model.

Figure 1 A proposed 'hub and spoke' model for femtosecond laser-assisted cataract surgery.
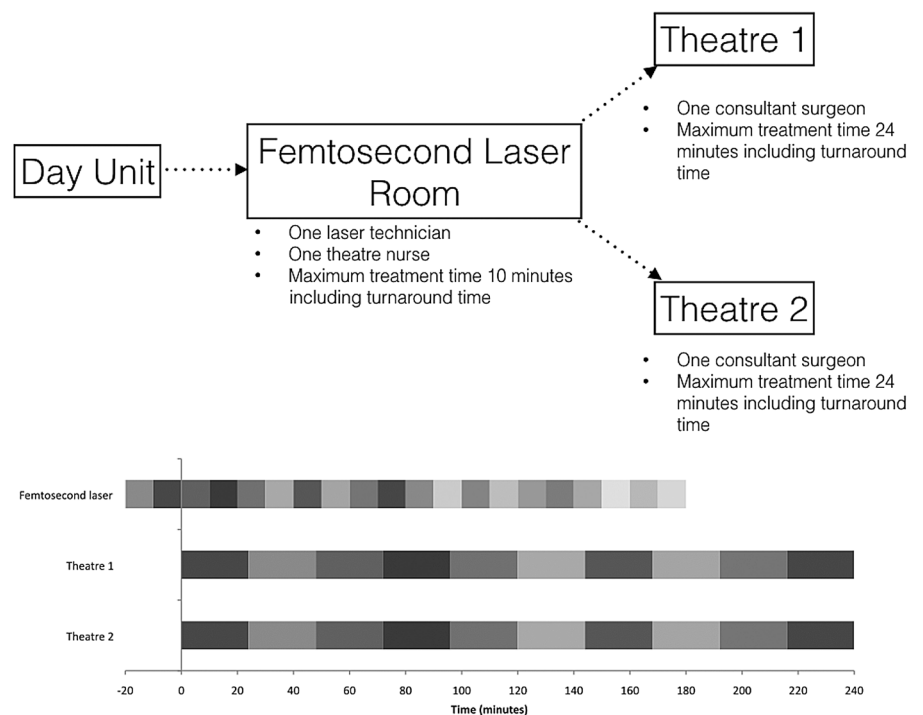
maximum of 24 min per case. These values are based on our own experience with the FL.

Sensitivity analysis

The model was constructed using Microsoft Excel (Microsoft Corp, Redmond, Washington, USA) based on the range of the above inputs (table 1). Univariate and bivariate sensitivity analyses were conducted by varying the inputs into the model to simulate the impact on the final service costs. The inputs chosen for the sensitivity analysis were as follows:

1. capital cost of the FL,
2. cost of the PI,
3. number of cases possible on a FLACS theatre list,
4. number of cases performed on a CPS list,
5. number of cataract operations required per week.

Threshold analyses were performed on the same variables as the sensitivity analyses to determine threshold values at which FLACS may break even with CPS. The results are reported as weekly costs.

RESULTS

The first model tested FLACS versus CPS based on an average number of seven cases currently performed on CPS cataract lists. Our model estimated that the current CPS service at its existing productivity was costing £433 per case. Using a model that incorporates one FL into one theatre list, and therefore assuming no increase in productivity, the laser increases the cost per case by £167 to £600. Based on these values, the CPS service would be 72% of the cost of a FLACS service.

Using the averaged and nominal values for our theoretical 'hub and spoke' model for FLACS, the use of the FL reduced the weekly theatre requirements from 8 CPS theatre sessions to 2.7 FLACS sessions with both theatres in the FL model running in parallel (total theatre sessions 5.4). This reduced the anticipated running costs of theatres, the ophthalmic day-case unit and staffing costs. However, the laser introduced additional costs into the model (FL equipment, supplies, maintenance and additional staff). Based on the nominal values, even with our hub and spoke model running optimally, the CPS service (average of £433/case) was found to be 86.3% of the cost of the FLACS service (average of £502/case).

The capital cost of the FL when amortised over its lifetime of 10 years was £505/week. Maintenance of the laser was £545/week. The cost of 1 week's worth of PI (n=55) at £135 each was £7356 (figure 2).

The model was not affected when we changed the salary of the laser operator from a midpoint registrar to a band 6 nurse as the hourly rates were of negligible difference (table 1).

Univariate sensitivity analyses were conducted by varying one variable at a time. Minimum and maximum values were obtained from the original data (table 2).
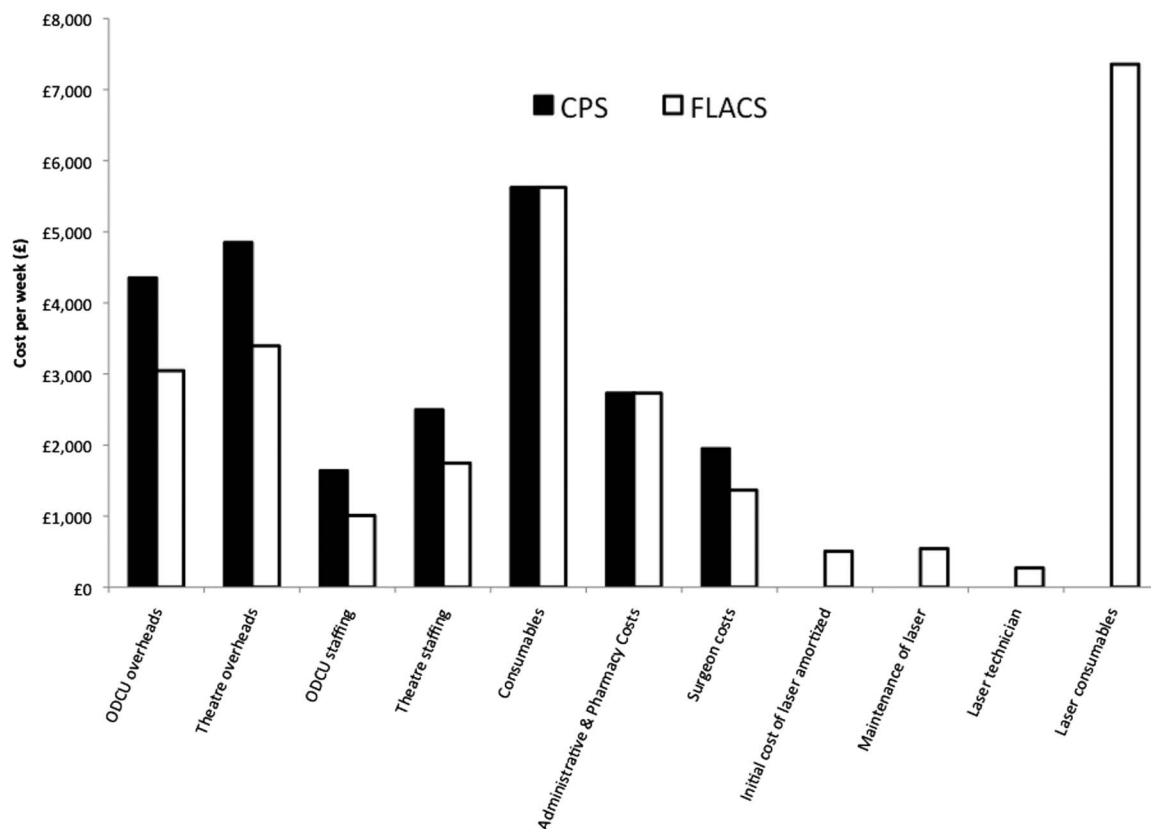

Figure 2 Comparison of the costs per week of conventional phacoemulsification surgery compared with femtosecond laser-assisted cataract surgery.

Table 2 (A) Univariate sensitivity analysis of the hub and spoke model based on range of values from data collected and (B) best-case scenarios for conventional phacoemulsification surgery and femtosecond laser-assisted cataract surgery

Input	Range of values	Values inputted into hub and spoke model	Cost of CPS service compared with FLACS (%)
A			
Cataract workload/week	Minimum	27	82.7
	Average	55	86.3
	Maximum	96	87.8
Number of cataracts on CPS list*	Minimum	5	**108.5**
	Nominal	7	86.3
	Maximum	9	73.8
Number of cataracts on FL list†	Minimum	8	78.6
	Nominal	10	86.3
	Maximum	16	**100.8**
Initial cost of FL	Minimum	£175 000	86.7
	Average	£262 500	86.3
	Maximum	£350 000	85.7
Cost of PI	Minimum	£99	92.8
	Average	£135	86.3
	Maximum	£170	80.5

	Cataract workload/week	Number of cataracts on CPS list	Number of cataracts on FL list	Cost of PI	Cost of CPS/case	Cost of FLACS/case	Cost of CPS service compared with FLACS (%)
B							
Best-case scenario for CPS	27	9	9	135	£371	£515	72.1
Best-case scenario for FLACS	96	5	10	50	£545	£381	143.2

Bold indicates where FLACS is less expensive than CPS option.
*Assuming 10 cases on FLACS list.
†Assuming seven cases on CPS list.

Only when the number of operations on a CPS list was reduced or the number of operations on a FLACS list was increased, could the model give an output in favour of FLACS. Best and worst-case scenarios were constructed for CPS and FLACS, by aligning the most important variables all in favour of one or other modality, with costs of £371 and £515 for CPS and £381 and £545 for FLACS, respectively (table 2B).

Univariate threshold analyses were performed to demonstrate the 'break-even' values of each input. Keeping all other inputs at their original values, the model could not find solutions by which the FL broke even when the capital cost of the FL or the number of operations performed per week was chosen. The costs of the services were equivalent if the true number of cases on a CPS list was 6, or if the FL could increase productivity to 16 cases/each theatre, or if the cost of the laser consumables was reduced to £66. It was thereby ascertained that these three parameters are the most important in this model for determining a cost-neutral scenario for FLACS.

Bivariate sensitivity analyses were performed using combinations of the above inputs. For example, table 3 shows the outcomes of the model when the capacity for the number of cases on CPS and FLACS is simultaneously tested. It shows that the FLACS service would be required to approximately double the number of operations possible during a theatre list for FLACS to break even. Table 4 tests the outcome of the model based on an assumption that the NHS can negotiate lower PI costs based on the provision of a large number of operations per year. It shows that FLACS cannot break even unless the cost of the PI is significantly reduced (to approximately £50 per case). Table 5 compares the cost of the PI against the number of cases on a FLACS list.

DISCUSSION

We have designed a hypothetical treatment delivery model based on a 'hub and spoke' service and utilising FLACS to improve the efficiency of cataract surgery in terms of number of cases undertaken per operating list. We then tested our model with sensitivity and threshold analyses to allow for variations or uncertainties.

Even with our optimised delivery model, FLACS is still more expensive than CPS based on current estimates of costs. To break even, the incorporation of FLACS would

Table 3 Cost of femtosecond laser-assisted cataract surgery versus conventional phacoemulsification surgery

Number of operations on FLACS list	Number of operations on CPS list (%)				
	5	**6**	**7**	**8**	**9**
8	99.0	87.1	78.6	72.3	67.3
10	**108.5**	95.5	86.2	79.2	73.8
12	**115.9**	**102.0**	92.1	84.7	78.9
14	**121.9**	**107.3**	96.9	89.0	82.9
16	**126.8**	**111.6**	**100.8**	92.6	86.3

Bold indicates where FLACS is less expensive than CPS option.
Bivariate sensitivity analysis: demonstrating relative costs of CPS service compared with FLACS when total number of cases on each theatre list are tested.

Table 4 Cost of femtosecond laser-assisted cataract surgery versus conventional phacoemulsification surgery

Cost of PI (£)	Number of cataract operations per year (%)				
	2000	**3000**	**4000**	**5000**	**6000**
50	**101.5**	**104.0**	**105.2**	**106.0**	**106.5**
75	95.9	98.1	99.2	99.9	100.4
100	90.9	92.8	93.8	94.4%	94.9
125	86.4	88.1	89.0	89.6	89.9
150	82.3	83.8	84.7	85.2	85.5

Bold indicates where FLACS is less expensive than CPS option.
Bivariate sensitivity analysis: demonstrating relative costs of CPS service compared with FLACS when cost of PI and total number of cases per year are tested.

Table 5 Cost of femtosecond laser-assisted cataract surgery versus conventional phacoemulsification surgery

Cost of PI	Number of operations on FLACS list (%)					
	8	**9**	**10**	**12**	**14**	**16**
50	92.9	98.6	**103.7**	**112.4**	**119.5**	**125.5**
65	90.0	95.4	**100.1**	**108.2**	**114.8**	**120.3**
80	87.3	92.3	96.7	**104.3**	**110.4**	**115.5**
100	83.9	88.5	92.6	99.5	**105.0**	**109.6**
120	80.8	85.1	88.8	95.1	**100.2**	**104.3**
135	78.6	82.6	86.2	92.1	96.8	**100.7**

Bold indicates where FLACS is less expensive than CPS option.
Bivariate sensitivity analysis: demonstrating relative costs of CPS service compared with FLACS when cost of PI and number of operations on FLACS list are tested.

have to approximately double the number of cataract operations performed per theatre list and indeed could not offer a cost-neutral solution if the number of cases on a CPS theatre list was 8 or more. Our model indicates that the greatest cost impediment to a FLACS service is the price of the PI (average cost £135/case) (figure 2), which represents almost 27% of the total cost per case. Unlike other service costs, the cost of the PI is not mitigated by potential increased productivity. It is therefore a major financial impediment to FLACS ever becoming cost-effective within the NHS, where the total tariff for each operation is fixed between £718 and £932.[16] [17] Potentially, this problem may be overcome by the manufacturer considerably discounting this cost to the NHS. In contrast to the PI, our financial model indicates that the costs of the laser itself, staffing and maintenance it were much less important (4.8% of total costs).

There are three important unknowns with regard to our model. First, we are awaiting clinical results from large RCTs comparing FLACS with CPS.[11] [12] The latest meta-analysis shows no significant advantages in terms of safety of FLACS over CPS.[10] However, there are advantages in terms of endothelial cell loss, effective phacoemulsification time and unaided visual acuity, albeit no difference in long-term best-corrected visual acuity and an increased risk of anterior capsular tear.[18] We assumed in our financial modelling that there are no differences in outcomes and complication rates between the two procedures. If, however, FLACS were to show significant advantages in terms of patient safety and outcomes then such improvements then this may have additional positive financial implications.

Second, potential gains in productivity from the FL are as yet unpublished and unrealised. Several studies investigating FLACS actually report decreased patient turnover with FLACS.[13] [19] [20] This is because at present typically the operating surgeon is performing the FL treatment as well as the subsequent lens extraction.

There are as yet no publications on the most effective way to design a FL-centric cataract service. We chose a 'hub and spoke' model based on one FL in a clean room, operated by an ophthalmic surgeon in training or ophthalmic technician/nurse. The FL then fed patients into two independent operating theatres, each with its own surgeon and support staff. This model is theoretical. It needs to be tested in the NHS setting to see if it is viable, and further work may need to be performed to determine a 'best-practice' and optimised efficiency model for FLACS.

Third, it is likely that the costs of the PIs would be reduced below the values quoted to us by the manufacturers, as a large public sector ophthalmology department performing several thousand operations per year could negotiate on costs and capitalise on market competition. As discussed above, this would considerably improve the financial burdens associated with implementing FLACS.

Abell and Vote[13] have previously designed a hypothetical model to derive cost-effectiveness of FLACS. In the absence of better evidence, conservative estimates were used for complication rates with FLACS. Their use of the FL resulted in reducing their theatre efficiency by two cases per list, and subsequently, they estimated the additional cost of FL to be AUS$1065 per case, AUS$750 of which were the direct costs from the FL and AUS$315 from lost productivity. Our model was based on using the laser to improve, rather than impede, productivity. We estimated the cost per case to be £158, of which £135 is the PI. We chose to amortise the costs of the laser over 10 years rather than only 3, but reducing the lifetime of the laser to 3 years increased the cost of each operation to only £180. This demonstrates yet again the greatest cost of FLACS is the cost of the PI rather than the laser itself.

In addition to the above, there are important limitations to mention regarding this hypothetical model. The model assumes that all patients are suitable for a high-volume FLACS theatre list. However, some patients may not be suited to FLACS or to a high-volume service, although the number of contraindications for FLACS is decreasing as experience with the technology improves.[21–23]

Departmental costs used in this model were obtained from a retrospective review of the financial records at four NHS foundation trusts. In order to ensure that the results were applicable to more than just one hospital with its associated population, we selected two teaching hospitals and two district general hospitals of varying sizes, with annual numbers of between ~1400 and 5000 cataract operations. These hospitals serve urban and rural populations (range ~275 000–823 000 served by each hospital) with a mixture of demographics (and include hospitals with one of the highest and one of the lowest cataract tariffs).[17]

The costs of consumables were assumed to be equal for FLACS and CPS. In reality, as the FL performs many stages of the procedure, the cost of some consumables may be reduced (vision blue, cystotome, etc) and some cataracts may no longer require any phacoemulsification.[24] Our model incorporates the salary of a registrar to operate the laser,[25 26] yet if FLACS becomes widely adopted within the UK, then technicians may be trained to perform this duty, perhaps at a reduced cost, but no money was saved when we modelled for the salary of a band 6 nurse to operate the laser.

Overall, this model demonstrates that FLACS could only be financially viable if its implementation into the NHS allowed significant improvements in efficiency in the number of cases treated per theatre list and/or if the cost of the PI was considerably reduced. Further research is required on the clinical outcomes of FLACS compared with CPS as well as real-world evidence of the effect to surgical efficiency afforded by this technology.

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