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MAIN ARTICLE

Direct cost comparison of totally endoscopic versus open ear surgery

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Abstract

Objective: Totally endoscopic ear surgery is a relatively new method for managing chronic ear disease. This study aimed to test the null hypothesis that open and endoscopic approaches have similar direct costs for the management of attic cholesteatoma, from an Australian private hospital setting.

Methods: A retrospective direct cost comparison of totally endoscopic ear surgery and traditional canal wall up mastoidectomy for the management of attic cholesteatoma in a private tertiary setting was undertaken. Indirect and future costs were excluded. A direct cost comparison of anaesthetic setup and resources, operative setup and resources, and surgical time was performed between the two techniques.

Results: Totally endoscopic ear surgery has a mean direct cost reduction of AUD$2978.89 per operation from the hospital perspective, when compared to canal wall up mastoidectomy.

Conclusion: Totally endoscopic ear surgery is more cost-effective, from an Australian private hospital perspective, than canal wall up mastoidectomy for attic cholesteatoma.

Key words: Costs And Cost Analysis; Otologic Surgical Procedures; Endoscopic Surgical Procedures; Cholesteatoma

Introduction

Endoscopic ear surgery is a relatively new technique that can be performed totally transcanal, using angled objective lenses to view areas that require soft tissue manipulation and bony drilling with the microscope.[1] One of the cornerstone indications for endoscopic ear surgery lies in the management of mesotympanic and attic cholesteatoma.[2,3] The technique has been shown to be as safe and efficacious as open approaches, with similar residual or recurrent cholesteatoma rates reported in the limited case series reviewed to date.[4]

Beyond safety and efficacy, when new surgical techniques are introduced, continual justification and rationalisation of expenditure are needed, as healthcare operates in a resource-limited environment. Whilst health gains that occur with improvements in technology often come at significant expense, it would be ideal if these gains were achievable at minimal cost or even with savings.

Complete analysis of the monetary value of a healthcare intervention occurs through examination of direct, indirect and future costs. Direct costs, such as surgical, anaesthetic, hospital and equipment costs, can be identified, and as a result are amenable to analysis. Indirect and future costs, such as faster discharge and return to work, and increased productivity, are more challenging to analyse, and critically require an analysis of quality of life.

From a hospital's perspective, when a new technique is being considered, the capital investment required often delays implementation. For this reason, the initial and ongoing direct costs of the new technique to the hospital are of importance to justify implementation. In the following analysis, the direct costs of totally endoscopic ear surgery from a private hospital perspective are compared to open surgery. Indirect and opportunity costs are excluded from this analysis. The null hypothesis of this study was that the totally endoscopic and open techniques have a similar direct cost to the hospital.

Materials and methods

A retrospective analysis was performed, from a single private hospital perspective, of the direct costs of the patient journey for an endoscopic approach versus canal wall up mastoidectomy for the resection of attic cholesteatoma conducted by a single surgeon (NP). Only costs borne by the hospital were included in the analysis, and therefore the cost of the surgeon and

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anaesthetist were excluded. Indirect and future costs were also excluded.

A chart review was conducted of 10 consecutive attic cholesteatoma patients who underwent a canal wall up mastoidectomy technique and 10 consecutive attic cholesteatoma patients who underwent a totally endoscopic technique between 2010 and 2016 at the same institution.

Cases were selected and matched according to disease volume, as assessed by pre-operative computed tomography and operative notes. Only cases limited to the mesotympanum and attic were included. For inclusion in the study, cholesteatoma did not extend posteriorly beyond the posterior aspect of the lateral semicircular canal, or inferiorly below the stapes suprastructure.

The relevant resources were identified by mapping the patient's health journey, similar to a previously described study,[5] with the decision tree implemented shown in Figure 1. The initial assessment for patients requiring open or endoscopic surgery overlaps, and, as a result, these investigations have not been included in the resource analysis. The tree diverges at the diagnosis, where patients who are identified as suitable candidates for totally endoscopic ear surgery are selected. Prior to totally endoscopic ear surgery, this group of patients would have undergone open surgery to access the attic. A comparison of the direct costs associated with each management branch was analysed from a hospital's perspective.

The senior author began to perform endoscopic ear surgery in 2012. Procedures performed from 2012 to 2013, when achieving proficiency with the new technique, were excluded. Proficiency was considered to be achieved on the surgical learning curve once more than 50 totally endoscopic ear surgical procedures had been performed. This is in keeping with the minimum 50 cases needed to achieve consistency in technique and outcomes set in previous surgical learning curve studies in otology.[6–8] Totally endoscopic surgery was defined as totally transcanal surgery performed using an endoscope exclusively, without the use of an operating microscope.

Endoscopic atticotomy was performed in six patients with a curved 2 mm diamond burr (Medtronic, Minneapolis, Minnesota, USA) and in four patients with a curette. A composite perichondrial tragal cartilage technique was used for tympanic membrane and attic reconstruction in the totally endoscopic ear surgery cases.

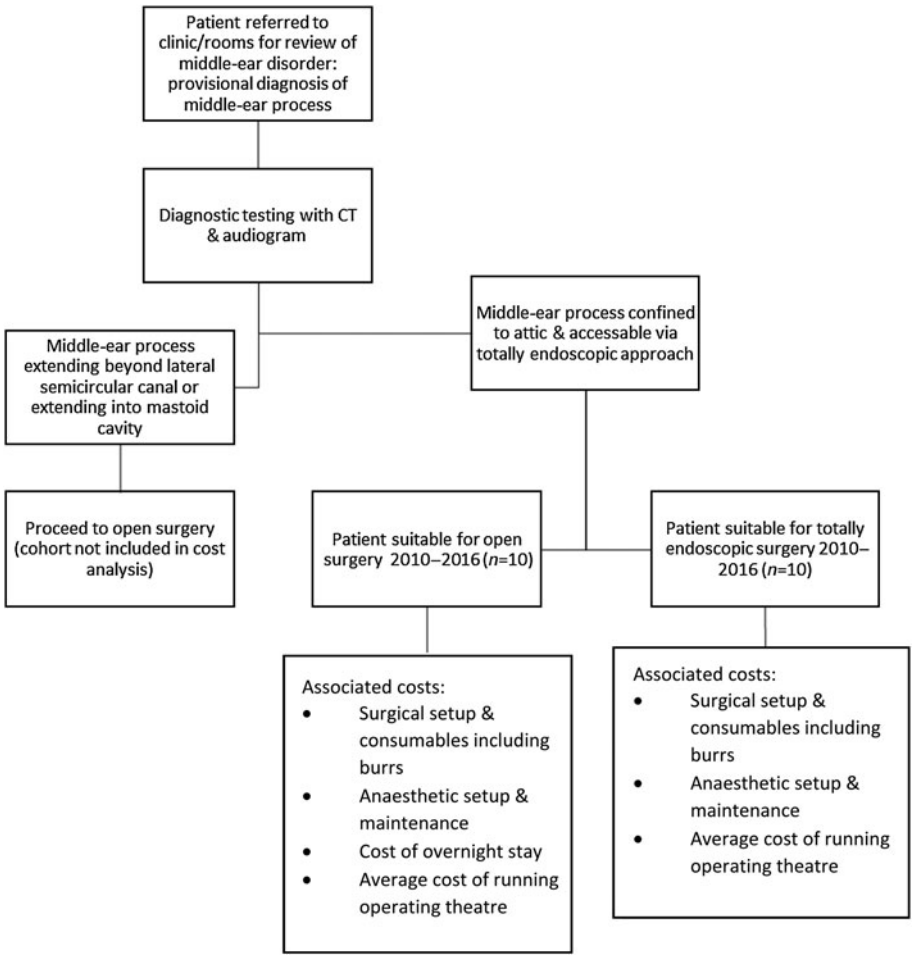

FIG. 1

Decision tree for patient's health journey. CT = computed tomography

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In the open approach, canal wall up mastoidectomy and canalplasty was performed with five burrs (Medtronic) using the Sheehy technique to allow optimal exposure of the anterior attic, and for post-operative inspection and/or toileting of the ear.[9]

A staged technique using Silastic was performed in both the totally endoscopic ear surgery and open approach groups. Temporalis fascia was used for tympanic membrane reconstruction in the canal wall up method. All cases of combined open and endoscopic techniques were excluded.

The costs and resources evaluated with this study were broken down into three major groups: anaesthetic resources, operative setup and resources, and average cost of running an operating theatre. The costs were deterministic and not patient-specific, based on the routine anaesthetic and surgical setup for open and endoscopic major ear surgery. Data regarding anaesthetic and surgical consumable costs were collected from the relevant nursing staff who organised the individual setup and sourced the consumables. The operating theatre costs were obtained from the chief finance officer of the hospital.

To estimate average hourly operating theatre costs, the complete patient journey time from anaesthetic bay to operation and first-stage recovery was included, as assessed by the anaesthetic chart. Specifically, calculations considered the following: all staffing costs, including anaesthetic, recovery, operating theatre and pre-admission costs; building and equipment depreciation; rent of land and space; maintenance; and gases costs. Administration, quality assurance and management were also accounted for within the analysis. Finally, a back office non-accountable correction of 10 per cent was added for staffing benefits and support services (food and laundry).

No discounting was applied, as future costs were not included in this hospital perspective analysis. All currency figures are shown in Australian dollars (AUD).

A two-sample *t*-test, which did not assume equal variances, was performed to compare the open surgery and totally endoscopic ear surgery groups.

Results

The cost of anaesthetic induction and maintenance has been calculated from anaesthetic setups. The results of this analysis, shown in Appendix I, do not include the cost of the anaesthetist, but do include anaesthetic support staff. The total cost of anaesthetic items for open surgery was $227.98 for the first hour. The total first hour cost in endoscopic ear surgery was $195.40, with a cost saving of $32.58. The increased price of anaesthetic induction relates to the use of laryngeal mask airway intubation in endoscopic cases as compared to endotracheal tube (ETT) intubation in open surgery cases. In open surgery cases utilising ETT, a further cost of paralysing and reversal agents are also included. The total cost per subsequent hour of maintenance anaesthesia was $11.65 for both open and endoscopic surgery.

The costs of operative case setups have also been compared. The quantities, per unit prices and total costs for equipment used in open and endoscopic surgery are provided in Appendices II–V. Again, the cost of the surgeon was excluded in this study, as this is not a cost that the hospital is responsible for in an Australian private hospital setting. The aggregate cost for the operative setup for open surgery was $1289.71. The open surgery setup includes the cost of sterilising a 2.7 mm 30-degree endoscope, and light lead and camera, which was $38.75. The totally endoscopic setup cost was $843.65. This represents a cost saving of $446.06 compared to the open surgery setup. These costs are for disposable items and for the sterilisation of reusable items. These costs do not assume the purchase of any new instruments or trays. Furthermore, these totals do not include the cost of burrs, which are dealt with separately in the calculation shown in Table I.

The operative logbook of the senior author (NP) demonstrated that the mean operating theatre time for anaesthetic induction, canal wall up mastoidectomy, atticotomy, closure, extubation and transfer to first-stage recovery was 214 minutes (range, 185–250 minutes; standard deviation (SD) = 23.7). In contrast, the mean time of the endoscopic approach was 151.5 minutes (range, 125–210 minutes; SD = 26.1), equalling a mean time saving of 62.5 minutes per case (95 per cent confidence interval = 30.4–94.6) (Appendix VI). A two-sample *t*-test, which did not assume equal variances, was performed, demonstrating a significant difference between these groups ($p < 0.0001$). The comparative total cost breakdown is given in Table I. The total operating theatre running costs were $1815.05 per hour.

TABLE I
COST BREAKDOWN FOR OPEN SURGERY VERSUS TOTALLY ENDOSCOPIC SURGERY

Cost parameter	Open surgery*	Totally endoscopic surgery†	Difference
Surgical setup cost	1289.71	843.65	446.06
Anaesthetic maintenance cost	11.65 × time	11.65 × time	12.14
Burrs cost‡	787.50	157.50	630.00
Average cost of running operating theatre ($1815.05 per hour)	6473.69	4583.00	1890.69
Total	8592.46	5613.57	2978.89

Data represent Australian dollars (AUD). *Mean operating time = 3.6 hours; †mean operating time = 2.5 hours. ‡Burrs were calculated to the closest full burr (mean number of burrs used in open surgery = 5.20, mean number of burrs used in endoscopic surgery = 0.60).

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Discussion

Totally endoscopic ear surgery involves a minimally invasive transcanal approach for the management of attic cholesteatoma, avoiding a post-auricular incision and mastoidectomy. Although data are still limited, there is a trend to indicate that the endoscopic technique is a safe and efficacious method for cholesteatoma removal. A recently published systematic review of 7 studies, comprising 515 patients, demonstrated no difference in the rates of recurrence or residual disease in those patients who underwent endoscopic resection, as compared to those who underwent open or combined surgical resection.[4]

Health economics becomes the major consideration for new technology introduction, once safety and efficacy have been demonstrated. When introducing a new method into a hospital, the initial capital outlay and ongoing costs are important to consider. This work demonstrates that, from an Australian private hospital perspective, there is a direct cost saving of $2978.89 per attic cholesteatoma case when the ear surgery is performed endoscopically by a surgeon trained in the technique. The cost savings largely occur through a reduction of operating time and burr use.

The reduction in surgical time is a result of not needing post-auricular incision, canalplasty and mastoidectomy to access the disease. In this analysis, a 62.5 minute reduction in surgical patient journey time equates to a mean cost saving of $1890.69. This figure should be considered in the context of an increased surgical time that occurs during the surgical learning curve, where the operative time may be the same or even longer than the open surgery method. Despite a longer surgical time in the learning period, there are still likely to be cost-effectiveness savings, as there is a reduction in burr use when transitioning to the endoscopic technique.

There is evidence that bone dust released in temporal bone dissections carries neural tissue, which may be a source of transmissible prion disease.[10] Re-useable burrs are not routinely used in the Australian healthcare system, given the potential for slow virus transmission. This necessitates the use of disposable burrs. The mean number of disposable burrs used in the two groups studied was less than one ($n = 0.6$) in endoscopic cases, compared to an average of five burrs per open surgery case (mean = 5.2 burrs, $p < 0.0001$). For the preferred make of burr used in the private hospitals of the senior surgeon, this equates to a cost saving of over $700.00.

There are several limitations in this study. Firstly, the sample size was small, and case matching between the endoscopic ear surgery and open surgery groups was not exact. The extent and nature of the cholesteatoma, and patient co-morbidities, would likely affect surgical journey duration, and therefore costs. Furthermore, the use of five to six burrs per open operation may be considered too high by many surgeons. Surgeons trained in atticotomy rather than an approach based on Sheehy's operative technique may only need to use two burrs.[9] Larger patient numbers, with different surgeons, in various institutions, will help to address these weaknesses, with ongoing prospective data being collected by the study group. Furthermore, there is a possibility of selection bias, as cases that involved the participation and training of a junior surgeon were not used in this analysis. Lastly, using a reduction in time to estimate surgical learning represents a weakness of the analysis. Surgical learning also involves many other facets, most importantly outcomes, which was not included in this work.

- **Totally endoscopic ear surgery is safe and comparable to open surgery, with improved cosmetic and quality-of-life effects**
- **Totally endoscopic ear surgery was compared to canal wall up mastoidectomy for attic cholesteatomas in the Australian private hospital setting**
- **Totally endoscopic ear surgery was quicker, by 56 minutes, and cheaper, by $2978.89, than open surgery**
- **Indirect and future costs were not assessed in this study**
- **The findings suggest an economic superiority for totally endoscopic ear surgery and may help private hospitals in deciding on its use**

Despite these limitations, a reduction of $2978.89 per case of attic cholesteatoma for the hospital when an endoscopic procedure is performed may represent a considerable underestimation of total cost savings. The analysis examined direct costs for the private hospital, but excluded indirect and potential future cost savings to the patient and healthcare system. Quality-of-life studies have yet to be published for the endoscopic technique; however, both anecdotally and logically, the lack of a post-auricular incision and mastoidectomy may result in improved quality of life and indirect economic gain. Furthermore, in unpublished data from our unit, less post-operative nausea and pain occurs, further extending the economic gains of the technique by reducing analgesic and anti-emetic use. The economic costs of an earlier return to work and improved quality of life were beyond the scope of this paper, but these are being addressed, with prospective quality-of-life patient data being gathered by the authors.

Conclusion

The above study demonstrated a considerable direct economic saving to the private hospital of almost $2978.89 per case of attic cholesteatoma. This figure may underrepresent the true economic advantage of the technique if indirect and future costs are included for the patient and society as a whole. This work

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provides hospitals and health policy stakeholders with some evidence to suggest that the endoscopic ear surgery technique may be economically superior to the open surgery technique.

References

1 Kozin ED, Gulati S, Kaplan AB, Lehmann AE, Remenschneider AK, Landegger LD *et al*. Systematic review of outcomes following observational and operative endoscopic middle ear surgery. *Laryngoscope* 2015;**125**:1205–14
2 Thomassin JM, Inedjian JM, Rud C, Conciatori J, Vilcoq P. Otoendoscopy: application in the middle ear surgery [in French]. *Rev Laryngol Otol Rhinol* (*Bord*) 1990;**111**:475–7
3 Tarabichi M. Endoscopic management of acquired cholesteatoma. *Am J Otol* 1997;**18**:544–9
4 Presutti L, Gioacchini FM, Alicandri-Ciufelli M, Villari D, Marchioni D. Results of endoscopic middle ear surgery for cholesteatoma treatment: a systematic review. *Acta Otorhinolaryngol Ital* 2014;**34**:153–7
5 Smith KA, Rudmik L. Cost collection and analysis for health economic evaluation. *Otolaryngol Head Neck Surg* 2013;**149**:192–9
6 Yung MW, Oates J. The learning curve in stapes surgery and its implication for training. In: Arnold W, Häusler R, eds. *Otosclerosis and Stapes Surgery*. Basel: Karger, 2007;361–9
7 Buchman CA, Chen DA, Flannagan P, Wilberger JE, Maroon JC. The learning curve for acoustic tumor surgery. *Laryngoscope* 1996;**106**:1406–11
8 Patel N, Shelton C. The surgical learning curve in aural atresia surgery. *Laryngoscope* 2007;**117**:67–73
9 Sheehy JL, Patterson ME. Intact canal wall tympanoplasty with mastoidectomy. A review of eight years' experience. *Laryngoscope* 1967;**77**:1502–42
10 Scott A, De R, Sadek SA, Garrido MC, Courteney-Harris RG. Temporal bone dissection: a possible route for prion transmission? *J Laryngol Otol* 2001;**115**:374–5

APPENDIX I
COST OF RUNNING AN OPERATING THEATRE PER HOUR

Description	Cost per hour (AUD$)
Staffing (anaesthetics, recovery, theatre, pre-admission unit) – Depreciation of building & equipment – Rent of land & space – Maintenance – Gases	1211.60
Anaesthesia maintenance drug cost	291.20
Behind the scenes – Quality assurance – Administration – Management	300.60
Office maintenance – Staffing benefits – Support services (food, laundry, etc.)	11.65
Total	1815.05

APPENDIX II
PER UNIT PRICING OF STERILISABLE ITEMS FOR OPEN SURGERY

Item	Number of items	ID number	Cost per item (AUD$)	Total cost (AUD$)
Major bundle	2	TP1	20.66	41.32
Prep set	2	620752	6.53	13.06
Prep bowls	1	617302	6.03	6.03
Sharps passer	1	620748	1.29	1.29
Light handle, non-disposable	1		1.75	1.75
Quiver	2		1.75	3.50
Jug	1	620749	1.60	1.60
Needle mat	1	620784	1.86	1.86
Insulated tip	1	509031	9.45	9.45
Bipolar lead	1	521496	9.10	9.10
Beaver blade straight	1	562046	31.53	31.53
Beaver blade down	1	562047	31.53	31.53
Beaver blade, micro, side-cutting	1	595507	2.65	2.65
Micro ear tray	1		68.80	68.80
Basic ear tray	1		74.40	74.40
Myringotomy tray	1		17.40	17.40
ENT Midas drill extras	1		14.30	14.30
ENT sucker tray	1		59.40	59.40
1288 camera & light lead	1		24.50	24.50
30-degree 2.7-mm endoscope	1		14.25	14.25
Midas drill, small	1		25.50	25.50
Heiss retractor	1		2.70	2.70
Foot & ankle pouch	1	500159	9.50	9.50
Fish hooks	1	562048	19.90	19.90
Total				485.32

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APPENDIX III
PER UNIT PRICING OF DISPOSABLE ITEMS FOR OPEN SURGERY

Item	Number of items	ID number	Cost per item (AUD$)	Total cost (AUD$)
Diathermy pencil	1	616575	10.65	10.65
Ciloxan drops	1		10.40	10.40
New microscope drape	1	571568	50.40	50.40
Disposable gown	1	563175	5.56	5.56
Single gown	1	TP9	4.42	4.42
Light handle, disposable	1	618830	1.60	1.60
No. 10 blade	2	500365	0.27	0.54
No. 15 blade	2	500367	0.27	0.54
No. 11 blade	2	500366	0.29	0.58
Neuro suction tubing	3	613284	3.07	9.21
Plastic	5	613290	0.70	3.50
Raytec	2	618823	0.06	0.12
Medium sponges	1	668828	2.00	2.00
1/2" (12.7 mm) Steristrips	1	502101	0.08	0.08
Cotton wool balls	1	618824	0.01	0.01
10 cm × 10 cm Melonin dressing	1	500814	0.28	0.28
Combine pad (dressing)	1	617289	0.22	0.22
10 cm crepe bandage	2	613236	1.06	2.12
Skin staples	1	566628	10.00	10.00
Skin staple remover	1	564770	4.79	4.79
Marking pen	1	627542	3.31	3.31
Asepto syringe	1	620788	2.10	2.10
3 ml Luer Lock syringe	1	626866	0.06	0.06
5 ml Luer Slip syringe	1	613287	0.07	0.07
20 ml Luer Slip syringe	2	613273	0.22	0.44
18 g needle	1	505421	0.05	0.05
Ioban 6640 antimicrobial incise drapes	1	500172	2.83	2.83
Fred anti-fog kit	1	500487	0.62	0.62
Intravenous giving set	1	601360	4.87	4.87
1 l intravenous Ringers solution	1	503738	4.33	4.33
Colorado needle	1	ref N103A	64.95	64.95
2/0 Silk 679 suture	1	679	2.75	2.75
3/0 Vicryl J442 suture	1	J442	3.36	3.36
4/0 Monocryl Y496 G suture	1	Y496G	7.37	7.37
Bone wax	1	W810 T	4.96	4.96
Nylon tape	1	W277	3.79	3.79
Instrument wipe	1	562841	8.20	8.20
GelFilm	1	502149	49.41	49.41
Flat thin Spongostan	1	509651	30.00	30.00
Xomed incrementing probe	1	522360	228.90	228.90
Xomed subdermal paired electrodes	1	523547	265.00	265.00
Total				804.39

APPENDIX IV
PER UNIT PRICING OF STERILISABLE ITEMS FOR ENDOSCOPIC SURGERY

Item	Number of items	ID number	Cost per item (AUD$)	Total cost (AUD$)
Major bundle	2	TP1	20.66	41.32
Prep set	2	620752	6.53	13.06
Prep bowls	1	617302	6.03	6.03
Sharps passer	1	620748	1.29	1.29
Quiver	2		1.75	3.50
Needle mat	1	620784	1.86	1.86
Insulated tip	1	509031	9.45	9.45
Bipolar lead	1	521496	9.10	9.10
Micro ear tray	2		68.80	137.60
Basic ear tray	1		74.40	74.40
Myringotomy tray	1		17.40	17.40
1288 camera & light lead	1		24.50	24.50
30-degree 2.7-mm endoscope	2		14.25	28.50
Midas drill, small	1		25.50	25.50

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APPENDIX V
PER UNIT PRICING OF DISPOSABLE ITEMS FOR ENDOSCOPIC SURGERY

Item	Number of items	ID number	Cost per item (AUD$)	Total cost (AUD$)
Disposable gown	1	563175	5.56	5.56
Single gown	1	TP9	4.42	4.42
Plastic	5	613290	0.70	3.50
Raytec	2	618823	0.06	0.12
1/2" (12.7 mm) Steristrips	1	502101	0.08	0.08
Cotton wool balls	1	618824	0.01	0.01
Asepto syringe	1	620788	2.10	2.10
3 ml Luer Lock syringe	1	626866	0.06	0.06
5 ml Luer Slip syringe	1	613287	0.07	0.07
20 ml Luer Slip syringe	2	613273	0.22	0.44
18 g needle	1	505421	0.05	0.05
Ioban 6640	1	500172	2.83	2.83
Fred anti-fog kit	1	500487	0.62	0.62
4/0 Monocryl Y496 G suture	1	Y496G	7.37	7.37
Instrument wipe	1	562841	8.20	8.20
GelFilm	1	502149	49.41	49.41
Flat thin Spongostan	1	509651	30.00	30.00
Xomed subdermal paired electrodes	1	523547	265.00	265.00
Foot & ankle pouch	1	500159	9.50	9.50
New microscope drape	1	571568	50.40	50.40
Ciloxan drops	1		10.40	10.40
Total				393.51

APPENDIX VI
CHART REVIEW OF OPERATIVE NOTES

Surgery	Pt no.	Total time in operating theatre (minutes)	Burrs used (*n*)	Year of surgery
Open*	1	215	5	2011
	2	220	5	2011
	3	190	5	2011
	4	185	6	2012
	5	200	5	2012
	6	245	5	2012
	7	230	6	2010
	8	220	5	2010
	9	185	5	2011
	10	250	5	2011
Endoscopic†	11	210	1	2014
	12	135	1	2014
	13	155	1	2015
	14	175	0	2015
	15	145	0	2015
	16	165	1	2015
	17	130	1	2015
	18	145	1	2015
	19	130	0	2015
	20	125	0	2016

*Mean total time in the operating theatre = 210.36 minutes (standard deviation (SD) = 24.53), with a range of 170–250 minutes; mean number of burrs used = 5.21. †Mean total time in the operating theatre = 153.93 minutes (SD = 26.90), with a range of 115–210 minutes; mean number of burrs used = 0.57. Pt no. = patient number

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