Changing Trends in Glaucoma Surgery within the Australian Public Health System

Short title: Sun *et al.* Glaucoma surgery in the Australian Public Health System

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ABSTRACT

Background: To examine trends in glaucoma surgery in Australian public hospitals over the 17-year period between 2001 to 2018.

Design: Retrospective audit

Methods: The Australian Institute of Health, Welfare and Ageing hospitalisation database was used to review ~~of~~ the total numbers of glaucoma surgeries performed from 2001 to 2018 in Australian public hospitals.

Results: Although there was an increase in the absolute number of trabeculectomy procedures from 2,926 to 3,244 over the 17-year study period, this represented a gradual decline in the age- and gender-standardised number of trabeculectomy procedures from 15.1 to 13.2 procedures per 100,000 persons. However, during this same period, there was a dramatic increase in the number of aqueous shunt insertions from 119 to 3,262 procedures, representing an age- and gender-standardised increase from 0.6 to 13.3 procedures per 100,000 persons. Negative binomial regression analysis revealed a decrease in trabeculectomy procedures of 1.1% per year, whilst there was increase in tube shunt insertions of 16.3% per year ($p<0.001$ for both). When stratified by age group, there was a statistically significant interaction in both trabeculectomy and tube shunt rates by age groups over time ($p<0.001$ for both). Trabeculectomy procedures decreased in those aged > 60years, compared to stable or increasing rates at younger age groups. Tube shunt insertion rates demonstrated a progressively greater increase in older age groups.

Conclusion and Relevance: Our findings demonstrate a changing trend in the surgical management of advanced glaucoma in recent years likely reflecting updated evidence regarding the role of tube shunt surgeries.

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INTRODUCTION

Glaucoma is the leading cause of irreversible~~preventable~~ blindness in the developed world, with an estimated prevalence of 3% in Australians aged over 49 and modelling suggests this figure will only increase in coming decades.[1,2] Trends in glaucoma management within Australia have been previously studied by three audits. Most recently, Newman and Andrew studied prescribing patterns and surgical procedures performed in the private health system over the 15-year period between 2003 and 2017.[3] Two older studies examined similar trends between 1994 to 2003, and 1994 to 2014.[4,5] In recent years there have been significant new developments in treatment strategies for glaucoma patients including newer topical agents, increased evidence surrounding the use of laser trabeculoplasty, as well as the growing number of minimally invasive glaucoma surgery (MIGS) devices.[6] However, despite the increasing popularity of MIGS surgery, the majority of currently available devices addresses only mild-to-moderate glaucoma, and long-term follow-up remains limited.[7] As such, the majority of severe, progressive glaucoma is still managed surgically with either trabeculectomy or tube shunts.

Australia's public health system provides universal healthcare with no out-of-pocket expenses ~~free of charge~~ to all citizens and is jointly funded by the federal and state governments. A proportion of Australians also elect to pay for private health care, whereby various costs are incurred by the patient, with subsidies provided by the federal government in the form of Medicare rebates. Private health care packages vary in coverage, with ophthalmic surgery usually requiring the most expensive, top-tier level of cover. The proportion of Australians with private health insurance has also steadily decreased over recent years, dropping to 44.2% in 2019. P~~All three p~~revious studies on various trends in glaucoma surgery within Australia have utilised data derived from the private health care system and as such, are missing the majority of patients who are treated in the public health system.[3-5] We thus sought to analyse the trends in various glaucoma surgeries performed in the public health system using data from the Australian Institute of Health, Welfare and

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Ageing (AIHW) to supplement existing studies and provide a more comprehensive analysis of surgical treatment of glaucoma in Australia.

METHODS

We performed a retrospective data review of the total numbers of glaucoma surgeries performed over the 17-year period between 2001 to 2018 in the Australian public healthcare system using the AIHW procedure cubes. The procedural data from the AIHW are~~is~~ derived from the National Hospital Morbidity Database, which each state and territory within Australia contributes. The data are~~is~~ derived from all public hospitals within Australia, and the proportion of missing data is negligible, representing <0.004% of cases per year.[8,9] The database collects the following information: type of procedure, year of procedure, patient gender, age group, and type of admission (either day or overnight admission). Procedure type is classified according to the second edition of the International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification (ICD-10-AM) and the 3rd to 6th editions of Australian Classification of Health Interventions (ACHI).

Procedural data included for this analysis included those classified under 'procedures for glaucoma' and included: '42746-04 trabeculectomy', '42752-00 insertion of aqueous shunt', '42749-00 revision of scleral fistula', '42746-05 other filtering (fistulisation) procedures for glaucoma not elsewhere classified', '42758-00 goniotomy' and '42770-00 destruction of ciliary body'. Procedural data for '42698-07 phacoemulsification of crystalline lens' was also collected for comparison.

Australian estimated resident population was obtained using online yearly estimates from the Australian Bureau of Statistics.[10] A population-adjusted number of procedures performed per 100,000 persons was performed to account for yearly increases in population size using the formula: (absolute numbers of procedures for year X/estimated resident population for year X) x 100 000. We calculated the rates of various surgical procedures including trabeculectomy, tube shunt procedures and phacoemulsification of crystalline lens. The total

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Commented [RC5]: The time period (< 2018) predates the 42705 number for combined phaco + iStent doesn't it?

Commented [RC6]: 42752 is actually insertion of drainage device incorporating an extraocular reservoir eg Molteno.

There is also some use of XEN implants in the public system in NSW, mainly at Westmead. I think they bill it as a 42746 (trab) but you could perhaps mention XENs briefly in the discussion. But there would have been very few or perhaps none prior to 2018.

number of trabeculectomy and tube shunt procedures were calculated in 20-year age groups (<20, 20-39, 40-59, 60-79 and >80) and the procedure rates were directly standardised using the age and gender structure of the Australian population in each relevant year. Trends in the number of surgeries performed per year were assessed using negative binomial regression models. In the models, the year was fitted as a continuous predictor, and age group, gender and the interaction between age group and gender were included as categorical predictors to control for population changes over time. Similarly, negative binomial regression models were used to assess if time trends in trabeculectomy and tube shunt surgeries varied according to age group. In the model, year (continuous), age group, gender and the interaction between age group and year were included as predictors. All analyses were conducted using Stata, version 16 and statistical significance set at $p < 0.05$.

Commented [RC7]: I like the use of a negative binomial model on the count data. Was this a better fit than a Poisson model? It usually is due to overdispersion.

RESULTS

From 2001 to 2018 the absolute number of procedures performed for glaucoma increased from 3,928 to 11,371. Although there was an increase in the absolute number of trabeculectomy procedures from 2,926 to 3,244 over the 17-year study period, this represented a gradual decline in the age- and gender-standardised number of trabeculectomy procedures from 15.1 to 13.2 procedures per 100,000 persons. However, during this same period, there was a dramatic increase in the number of aqueous shunt insertions from 119 to 3,262 procedures, representing an age- and gender-standardised increase from 0.61 to 13.3 procedures per 100,000 persons (Figure 1 and Table 1).

Figure 1: Rates of Trabeculectomy and Tube Shunt Surgery from 2001 to 2018

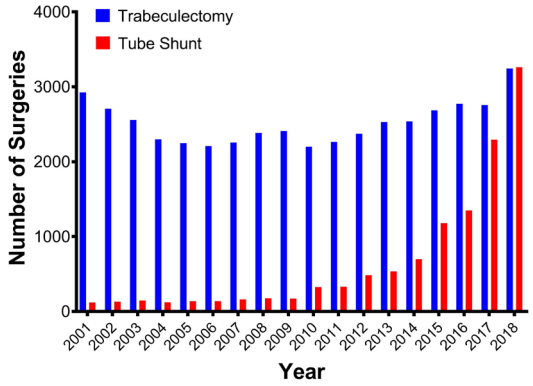


Table 1: Number and Incidence of Trabeculectomy, Tube Shunt and Phacoemulsification Surgeries from 2001 to 2018

Year	Trab	Tube	Phaco	Incidence (per 100,000 Population)		
				Trab	Tube	Phaco
2001	2926	119	121568	15.1	0.6	626.2
2002	2706	129	131209	13.8	0.7	667.7
2003	2557	144	140892	12.9	0.7	708.2
2004	2298	120	144946	11.4	0.6	720.1
2005	2246	136	159526	11.0	0.7	782.2
2006	2208	135	165848	10.7	0.7	801.3
2007	2255	160	168507	10.7	0.8	801.8
2008	2384	174	180187	11.1	0.8	840.7
2009	2409	170	189446	11.0	0.8	862.9
2010	2199	322	197002	10.0	1.5	897.4
2011	2264	330	195906	10.3	1.5	887.8
2012	2373	485	206064	10.6	2.2	922.4
2013	2531	535	211973	11.1	2.4	932.6
2014	2535	699	206064	11.0	3.0	891.4
2015	2686	1176	211973	11.3	4.9	891.2
2016	2773	1348	250912	11.6	5.7	1052.0
2017	2755	2294	260114	11.2	9.3	1057.5
2018	3244	3262	268872	13.2	13.3	1092.9
Relative increase* %	**10.9**	**2641.2**	**121.2**	**-12,6**	**95.5**	**74.5**

*2018 value minus 2001 value divided by 2001 value multiplied by 100

Other filtering procedures increased from 0.86 (n=166) to 2.04 (n=501) per 100,000, cyclodiode laser increased from 1.36 (n=264) to 2.13 (n=523) per 100,000, while revision of scleral fistula increased from 1.32 (n=256) to 4.16 (n=1021) per 100,000 persons during the study period. Goniotomy rates remained at <1 per 100,000 persons (range 8-72 per year) until 2015 when minimally invasive glaucoma surgery (MIGS) devices were approved by the Therapeutic Goods Administration and began being billed under the same code. Thereafter, there was a steep rise to 517 procedures in 2015 (2.15 per 100,000 persons) and increasing further to 966 in 2016 (4.05 per 100,000), 2822 in 2017 (11.47 per 100,000) and 2054 in 2018 (8.35 per 100,000). Phacoemulsification cases increased from 626.2 (n=121,568) to 1092.9 (n=268,872) per 100,000 persons during this time.

The percentage of patients undergoing trabeculectomy as a day surgery procedure increased from 64.6% in 2000 to 87.0% in 2018. The increase in day surgery cases for tubes was much higher over the study period, from 28.6% in 2000 to 90.0% in 2018.

Negative binomial regression analysis revealed a decrease in trabeculectomy rate of 1.1% annually (incidence rate ratio 0.989, 95% confidence interval (CI) 0.983-0.994), whilst there was increase in tube shunt insertion of 16.3% annually (incidence rate ratio 1.163, 95% CI 1.147-1.179) ($p<0.001$ for both).

When stratified by age group, negative binomial regression analysis revealed a statistically significant interaction in both trabeculectomy and tube shunt rates among age groups over time, suggesting temporal trends differed among the age groups ($p<0.001$ for both, Tables 2 and 3). While trabeculectomy procedures decreased in those 60-79 and >80 years of age, they were stable amongst 40-59, and decreasing amongst <20 and 20-39, years of age (Table 2 and Figure 2). In contrast, tube insertion rates demonstrated greater increases in progressively older age groups (Table 3 and Figure 2). When stratified by gender, negative binomial regression analysis suggested a possible difference by gender in trabeculectomy

procedure trends (p=0.052). Amongst females, trabeculectomy procedures decreased by 1.7% per year (CI 0.976-0.991, p<0.001) as compared to males, where trabeculectomy procedures were non-significantly decreasing by 0.1% per year (CI 0.986-1.000, p=0.08). There was no significant interaction by gender for tube insertion procedures (p=0.49).

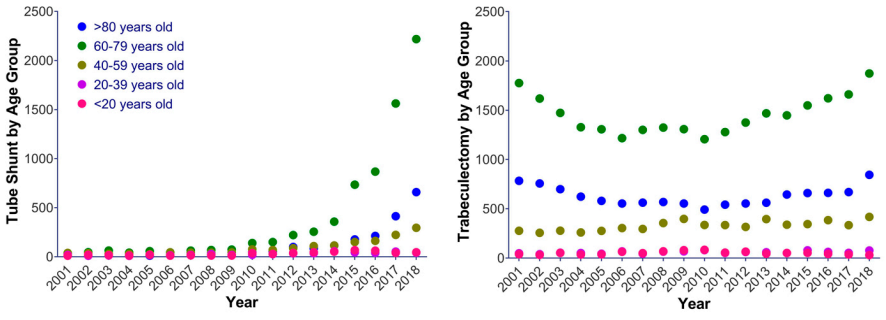
Table 2: Temporal Trends in Trabeculectomy According to Age Group

Age Group	Rate Ratio	95% Confidence Interval	p-Value
<20	0.992	0.968-1.016	0.519
20-39	1.001	0.993-1.020	0.357
40-59	1.011	1.003-1.020	0.003
60-79	0.979	0.972-0.986	<0.001
>80	0.973	0.963-0.983	<0.001

Table 3: Temporal Trends in Tube Shunt According to Age Group

Age Group	Rate Ratio	95% Confidence Interval	p-Value
<20	1.095	1.066-1.125	<0.001
20-39	1.078	1.059-1.097	<0.001
40-59	1.131	1.112-1.151	<0.001
60-79	1.238	1.209-1.238	<0.001
>80	1.237	1.201-1.273	<0.001

Figure 2: Age-Specific Trends in Trabeculectomy and Tube Shunt Surgeries



DISCUSSION

This study represents the first to analyse trends in glaucoma surgery within the Australian public health care system and is the first to report on age and gender characteristics of Australian patients. We found a slight decrease (1.14%) in the rate of trabeculectomy over the 17-year study period as compared to a dramatic increase in tube shunt insertion of 16% annually over the same time period. These trends appeared to vary by age group. Trabeculectomy procedures decreased in those aged >60years, compared to stable or increasing rates at younger age groups. Tube shunt insertion rates demonstrated a progressively greater increase in older age groups. - Finally, trabeculectomy procedures appeared to be decreasing by a greater extent in females compared to males, whereas tube insertion trends were similar in both genders. These findings demonstrate a changing trend in the surgical management of advanced glaucoma in recent years, likely reflecting updated evidence regarding the role of tube shunts as per the Tube vs Trabeculectomy studies.[11]

Traditionally trabeculectomy was preferred over tube shunt surgery, which was previously reserved for those with failed trabeculectomy or at high risk of trabeculectomy failure. However, changing patterns of practice have since emerged following the Tube Versus Trabeculectomy study in 2014 and subsequently the Primary Tube Versus Trabeculectomy trial in 2018,[11,12] which have supported an expanding role of tube shunt procedures beyond refractory glaucoma.[13] This evolving practice pattern has been observed worldwide, with increasing rates of tube shunt surgeries relative to trabeculectomy found in American, British and Canadian studies.[14-17] Most recently in United States, from 2008 to 2016 the overall number of trabeculectomies performed on fee-for-service Medicare patients decreased from 25,610 in 2008 to 18,925 in 2016, while there was a 20.2% increase in the number of tube shunt surgeries from 11,615 in 2008 to 13,960 in 2016.[15] In the United Kingdom, rates of trabeculectomy remained relatively stable from 2003 to 2012 at 9.06 to 10.76 per 100,000 persons, whilst tube shunt insertions increased six-fold from 0.3 per 100,000 in 2012 compared to 1.88 per 100,000 persons in 2003, with the highest increase in those aged

older than 60.[14] Similarly in Ontario, where trabeculectomy rates remained similar between 1992 to 2012, tube shunts increased more than five-fold in the same period and represented one-third of all glaucoma filtration procedures performed in 2012.[16]

We found significantly higher rates of tube shunt surgery and a more rapid increase over time relative to trabeculectomy when compared to the previous three Australian studies which included surgical data from the private health system only. With less than half of all Australians holding private health care currently, and variations in health care coverage seeing many patients still electing to be treated publicly, the majority of glaucoma surgeries in Australia remains incompletely captured using this database alone. This is reflected in the significantly lower rates of both trabeculectomy and tube surgeries reported by previous studies within the same time period. For example, Newman and Andrew reported only 272 tube surgeries in 2017 performed privately whilst our data revealed 2,294 tube shunt procedures performed in the public health care system for the same year.[3] Similarly, Kerr et al. reported 1,575 trabeculectomies reimbursed privately in 2014,[4] as compared to 2,535 in the same year in our study. Furthermore, the previous studies reported rates of trabeculectomy remaining significantly higher than tube insertion in recent years whilst our findings demonstrate that trabeculectomy and tube shunt procedures are now being performed at equal rates in Australian public hospitals. Newman and Andrew[3] reported trabeculectomy rates of 8 per 100,000 persons compared to tube shunt insertions at just 1 per 100,000 in 2017, as compared to our higher but similar rates of trabeculectomy and tube shunt surgery of 11.2 and 9.3 per 100,000 persons respectively in the same year. It is possible this reflects differing patient demographics treated in the private and public health system, with more complex and advanced glaucoma cases referred to tertiary care public hospitals.

Recent advancements in MIGS devices have seen a dramatic increase in uptake amongst ophthalmologists worldwide.[7] In Australia, the availability of MIGS in in public hospitals

varies significantly and the majority of these procedures are still performed privately. Initially the use of MIGS was billed under the 'goniotomy' code until 2017, when a separate item number was created for a combined cataract extraction and trans-trabecular MIGS insertion and as of May 2020, there is now a standalone MIGS insertion code. Although there was a significant increase in the number of procedures billed under the 'goniotomy' code from 2015 when MIGS became TGA approved in Australia, rates remained significantly lower than those previously reported using private health care data. In 2017 for example, there were 2822 procedures billed under the 'goniotomy' code as compared to 4262 MIGS procedures in the same year in Newman and Andrew's study.[3] Furthermore, the separate item code for cataract combined with trans-trabecular MIGS device was not reported in the AIHW dataset and it is unknown what proportion of the surgeries billed under 'goniotomy' were MIGS, although prior to 2015, cases were stable at <100/year. Our findings suggest that the majority of glaucoma surgery presently performed in Australian public hospitals are still trabeculectomy and tube shunt procedures, but it would be important to review these trends in another few years to determine uptake of MIGS in Australian public hospitals.

As a comparison, we also analysed overall rates of cataract surgery during the same time period using the code for 'phacoemulsification of crystalline lens' and found a steady increase over the same time period, as compared to a decline in trabeculectomy and dramatic increase in tube shunt surgeries. This likely reflects increasing demand for public health services to the high incidence of cataract development amongst the increasing ageing population of Australia,[18] with similar increases found in the United States and United Kingdom.[19,20] Although the literature regarding effect of cataract surgery on intraocular pressure in patients with open-angle glaucoma remains mixed,[21,22] evidence does suggest that cataract surgery does appear to lower intraocular pressure in early glaucoma patients.[23] Furthermore, with the increasing popularity of trans-trabecular MIGS devices often combined with cataract surgery aimed at preventing progression of mild to moderate glaucoma, it will be interesting to investigate how this trend then affects future rates of trabeculectomy and

tube shunt procedures. With modelling suggesting that Australia's ageing population will result in significantly higher rates of glaucoma over the next several decades,[2] the economic impact of various ophthalmic interventions to address the burden of visual impairment in Australia's population will become increasingly important.

Although our study provides valuable information regarding the surgical management of glaucoma in Australian public hospitals previously not reported, our results should be taken together with previous studies of practice patterns within the private health care system.[3-5] Limitations of our study include the reliance on diagnostic coding, which could have contributed to under- or overestimation for certain procedural codes. Furthermore, as our data relied on hospital admission data, procedures performed in outpatient treatment rooms were not captured, and this is particularly relevant for cyclodiode laser, which is now increasingly performed in an outpatient setting and thus our reported numbers are unlikely to represent actual rates of cyclodiode performed in Australian public hospitals. Our study also lacked specific patient-, hospital- and state-specific information which might have provided additional insights into the observed trends.

In summary, our study demonstrates changing trends in the surgical management of glaucoma within Australian public hospitals, with tube shunt insertion now performed as frequently as trabeculectomy in recent years. These trends are likely to change further with the increased uptake of MIGS, as well as improved early detection and non-surgical management of glaucoma.

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