Hospitalisations for third molar removals and oral cellulitis: reflecting the inverse care law in Australia

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I, Abed Aktam Anjrini, certify that:

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Abstract

The purpose of this thesis was to study two dental conditions in Australia that lead to hospital admissions: removal of impacted wisdom teeth (third molars); and oral cellulitis.

In the first part of this thesis, a new model of international comparative analysis was established using the International Classification of Disease. This novel method compared 3 health care systems (UK, France, and Australia) in regard to hospitalisations for impacted third molar extractions. The study covered the period of 10 years (1999-2009) and studied the significance of the presence of guidelines (UK) compared to health care systems without guidelines (France and Australia). This international comparison revealed significant differences in rates of admission, with Australia having rates approximately 7 times more than England, and 50% more than France. These results could be explained by the implementation of guidelines for impacted third molars in the United Kingdom, and the absence of similar guidelines in France and Australia.

The economic significance in Australia of surgical removal of impacted third molars for prophylactic/orthodontic retention purposes was analysed, as well as the cost effectiveness of the proposed watchful monitoring of pathology-free impacted third molars versus their surgical removal. The estimated number of hospitalisations for impacted teeth in Australia in 2008/2009 for the age group 15–34 years was 97,949. The estimated average annual direct cost was $350 million, the indirect cost was $181 million and total cost was $531 million. Individual cost of the
watchful monitoring strategy over 20 years was $1,077, with an annual estimated cost of $53. The proposed guidelines would lead to an annual figure of 83,850 individuals avoiding hospitalisation and shifting to watchful monitoring strategy, and an annual reduction of costs ranging between $420–513 million.

In the second part of this thesis, the trends for hospitalisations for oral cellulitis in Western Australia were analysed and tested the hypothesis that oral cellulitis is associated with poverty and indigenous status. The parameters included: age groups, socioeconomic status and Indigenous status. An international comparison with UK was included in the study. The study used data derived from the Western Australian Hospital Morbidity Data System (HMDS) for 10 years (1999-2008). There was a strong association between socioeconomic status and rate of cellulitis, with the most disadvantaged quintile of the population (1.7% of residents) accounting for 34% of cellulitis cases. Aboriginal and Torres Strait Islander people were almost 7 times over-represented, compared with non-Indigenous Western Australians. Next the GIS (Geographic Information System) was applied to models, to determine regions of Western Australia that are predicted to have a high number of the oral cellulitis cases. This type of predictive model can assist in focusing primary health resources to areas of risk and thereby reduce the substantial costs, and risks, associated with treating this condition.

Finally, a risk indicator applicable on a national level to isolate at relatively high resolution in Australia regions where oral cellulitis risk is high using GIS was established. The distribution of the population at risk of oral cellulitis was studied with the effect of distance from the centre of the capital city of each state. The Australian population belonging to highest risk category was not equally distributed amongst Australian states, with Northern Territory having 12.2 % of its population (26011) belonging to category 5 (very high risk). The majority of patients in that
population (87.8%) live more than 100 km away from the capital city, Darwin. A general trend amongst Australian capital cities was the low number of patients at high risk, within 5 km from General Post Office (GPO).

The research contained in this thesis indicates that there is a large use of resources towards the arguably unnecessary prophylactic removal of third molars. Moreover, that is largely centred on the more affluent sectors of Australian society. In view of the findings related to the association of oral cellulitis with poverty and indigenous status, more resources should be dedicated to dealing with the prevention of this potentially fatal condition affecting the poorest sectors of society.
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Thesis Format and Authorship Declaration

The regulations of The University of Western Australia provide the option for candidates for the Degree of Doctor of Philosophy to present their thesis as a series of papers which have been published in refereed journals, manuscripts that have been submitted for publication but not yet accepted, or manuscripts that could have been submitted.

This Thesis is comprised of an introduction, 3 published original research papers in refereed journals, 2 submitted original research manuscripts (not yet accepted) and a General Discussion. The Thesis was conducted under the supervision of W/Professor Marc Tennant (Coordinating Supervisor), A/Professor Estie Kruger and E/Professor John McGeachie. I declare that all of the work in this thesis is my own. For the co-authored published and submitted work, I was the primary author for all 5 papers/manuscripts and my contribution was 80%.

Dr Abed Aktam Anjrini (PhD Candidate)

I, W/Professor Marc Tennant, certify that the student statement regarding his contribution to the work is correct.

W/Professor Marc Tennant (Coordinating Supervisor)
Publications arising from this thesis


Anjrini AA, Kruger E, Tennant M. Mapping isolation of risk for sporadic conditions: Oral cellulitis in Western Australia (Submitted but not yet accepted-under review). Asia Pacific Journal of Health Management

Chapter 1: General Introduction

In Australia, inequality exists in terms of oral health, with some groups within the Australian population experiencing much poorer oral health and persistent levels of oral disease than the large majority.¹

The reasons for this situation are complex and multifactorial. One aspect however that is often mentioned is access to primary oral health services (this refers to two specific dimensions of access, namely spatial access and affordability of dental care). The inverse care law applies in Dentistry², with the availability of good dental care varying inversely with need of the population it serves.

Hospitalisations for dental conditions are believed to be largely avoidable if timely and adequate treatment in primary care is provided³. The non-linear nature of the relationship between the levels of primary healthcare and hospitalisation has been established. As it was identified that both the lack and excess in primary healthcare lead to higher rates of hospitalisation, creating a U-shaped relationship³–⁵.

To clearly illustrate and analyse this relationship, it was decided to focus on two conditions that were very strongly associated with socio-economic status, but on opposite ends of the advantage-disadvantage spectrum: the removal of third molars⁶ (very often on an elective or prophylactic basis); and oral cellulitis (where hospitalization is mostly unavoidable due to the serious nature of the condition).
The hypothesis is that easy access to primary care (in terms of spatial access and affordability) might lead to possibly unnecessary hospitalisations, and on the other end of the scale, that too little access to primary care might also lead to potentially avoidable hospitalisations (that could have been prevented if timely care provided).

In a cost-conscious health care system, it is an essential goal that all people receive the treatment they need, and nobody receives unnecessary treatment. The economic impact of medical procedures on the individual, the healthcare authorities and insurance companies, along with the loss of productivity, play a paramount rule in the development of healthcare policies and guidelines.

Cost effectiveness (CE) analysis could be used to enhance the allocative efficiency of the health system\(^6\). When comparing two management strategies, if one is found to be relatively cost-ineffective, and the other, which is not undertaken fully, is relatively cost-effective, resources could be reallocated across interventions to improve population health\(^6\).

It has long been established that impacted teeth need to be removed when they show any sign of associated pathology and/or severe symptoms\(^7\). However, in a considerable percentage of the extraction cases prophylactic extraction of pathology-free impacted teeth has been reported. The reasoning behind this controversial prophylactic procedure is the prevention of pathological changes, decrease in future surgical complications and improvement in post-orthodontic treatment retention (decrease of late incisor crowding). The justification for this prophylactic surgery is disputed and has been debated for many years. In a recent update, and after extensive review of the literature, the Cochrane Database Systematic Reviews concluded that there is insufficient evidence supporting the removal of asymptomatic impacted third molars. Furthermore, the authors
described watchful monitoring of these asymptomatic impacted teeth as a more prudent strategy.  

The possibility of substantially decreasing the number of hospitalisations for impacted tooth extraction led to the introduction of the NICE Guidelines in 2000 in the UK. They were based mainly on the review of Song et al. and have been developed by a committee of 24 experts in health economics, epidemiology, public health and surgery. They recommended that the practice of extraction of pathology-free impacted third molars should be discontinued. These unique guidelines have been followed by all NHS (National Health Services) dentists in England for the last 18 years.

In the first part of this thesis, a new model of international comparative analysis was established using the International Classification of Disease. This novel method compared 3 health care systems (UK-England, France, and Australia) in regard to hospitalisations for impacted teeth extractions. The study covered the period of 10 years (1999-2009) and studied the impact of the presence of guidelines (England, UK) compared to health care systems without guidelines (France and Australia).

The next step of this part was to analyse the economic impact in Australia of surgical removal of impacted third molars for prophylactic/orthodontic retention purposes. Also, this study examined the cost–effectiveness of the proposed watchful monitoring of pathology-free impacted third molars versus their surgical removal. To do so, the numbers and characteristics of hospitalized patients for removal of impacted teeth were estimated and used to develop a national-level cost model of both the direct and indirect costs of hospitalisations in Australia. This model was then used to compare both strategies and calculate possible cost
savings in the scenario where Australia would adopt guidelines comparable to those of the UK (England).

The subject of the second part of this thesis is: oral cellulitis, an oral health condition that also may require admission to hospital. Cellulitis of the floor of the mouth and submandibular region is a rare condition that mostly (80%) develops as a result of caries-pulpal necrosis and/or periodontitis, pericoronitis associated with unerupted and partially erupted teeth. The most serious clinical presentation of cellulitis is Ludwig Angina, a potentially fatal, rapidly spreading soft-tissue infection with a tendency to cause oedema, distortion, and obstruction of the airway. In most cases of cellulitis hospital admission is required to drain pus and remove the cause.

Oral infections have been associated with poverty and low socio-economic status in both UK\textsuperscript{11} and India\textsuperscript{12} and could be used as an indicator of significant dental disease in a society.

In Australia, 3\% of the population are Aboriginal and Torres Strait Islanders\textsuperscript{13}, who are reported to suffer from low level of dental health\textsuperscript{14} and are generally more likely to be admitted to hospital\textsuperscript{15}.

The plan was to study, in Western Australia, the trends for hospitalisations for oral cellulitis and to test the hypothesis that oral cellulitis is associated with poverty and indigenous status. The parameters include Age groups, socioeconomic status and Indigenous status. An international comparison with UK (England) was included in the study and used data derived from the Western Australian Hospital Morbidity Data System (HMDS) for 10 years (1999-2008).
A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. The science of GIS is developing at a global level and has many applications regarding dental and epidemiological research. This discipline may act as a decision-making tool in dental public health and it might contribute to the formulation of policies. Worldwide innovative ways are being developed to harness the data integration and spatial visualization power of GIS.

The use of various information technology services and software, to solve public health issues has an exponential increase and has been vital to the understanding and treatment of health problems in different geographic areas. GIS applications include both hardware and software systems. These applications may include cartographic data, photographic data, digital data, or data in spreadsheets. The latter can include population demographics such as age, income, and ethnicity, and can then be used to produce maps illustrating geographical disease distribution. It has been successfully used previously, to geographically isolate the risk areas for sporadic disease occurrence.

The following step was to apply GIS models, (based on a risk location indicator developed from first step), to determine regions of Western Australia that are predicted to have a high number of the oral cellulitis cases. This type of predictive model can assist in focusing primary health resource to areas of risk and thereby reduce the substantial costs, and risks, associated with treating this condition.

In the following chapter the aim was to establish a risk indicator applicable on a national level to isolate at the highest possible granularity in Australian regions where oral cellulitis risk is high. The majority of the Australian population live in the major cities (Melbourne, Sydney, Brisbane, Adelaide, Perth, Darwin, Canberra and
Hobart), and people who live in regional and rural areas are reported to have higher rates of dental caries\textsuperscript{17}. Accordingly, it was decided that the distribution of the population at risk of oral cellulitis will be studied with the effect of distance from the centre of the capital city of each state.

This thesis, by investigating those two dental related hospitalisations, could help cast light upon the contrasting inequality of access to dental health services within the Australian health care system. Furthermore, it could show how the absence or presence of regulating guidelines may affect the rate of prophylactic procedures. This could potentially allow health authorities to more efficiently, and cost effectively, manage care and target it to those most in need.

References

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Chapter 2: Literature Review

**Impacted third molars (wisdom teeth):**

**Prevalence of third molars impactions:**

Third molars (also called “wisdom” teeth) are usually the last teeth to erupt (at age 17-26 years), and is the most posterior tooth in each quadrant of the mouth. Tooth impaction, in the majority (over 90%) of cases as reported by Chu et al\(^1\), is associated with third molars. The possible reasons behind this impaction are lack of space, obstruction, or an abnormal position in the jaw. (Dodson 2010)\(^2\).

There is high prevalence (18-68%) of third molar impactions in the general population \(^3\)-\(^6\). Kanneppady et al.\(^3\) studied 667 radiographic OPG records of Malaysian patients of three different ethnicities and found the prevalence of impaction of third molars to be 67.6%. In a radiographic study\(^4\) of one thousand orthopantomograms (OPGs) of 20-40 years old Singapore Chinese patients, 68.6% of OPGs showed at least one impacted third molar. A similar study from Sweden\(^5\) investigated the prevalence of impacted third molars in 257 dental students between 20 and 39 years old and found one or more impacted third molars in 33% of the individuals. Another study from Saudi Arabia, analysing 3800 OPGs found that a total of 713 (18.76%) patients had impacted third molars \(^6\). Recently, Carter and Worthington\(^7\)
(2016) evaluated the prevalence of third molar impactions worldwide in individuals over 17-year-old. They applied meta-meta analysis on 49 studies involving 83,484 individuals and found worldwide third molar impaction prevalence to be 24.40%.

Clinical Effects of retaining impacted third molars

Impacted wisdom teeth could become associated with pathology. This includes pericoronal infection, cyst formation such as dentigerous cysts, tumours such as ameloblastoma, resorption or caries to adjacent teeth. Pericoronal infection: Recurrent pericoronitis (infection of the soft tissues around the crown of partially erupted tooth) has been reported (Patel et al 2017) to be the most frequent indication for lower third molar removal (33.8%)\(^9\). This finding was in consistency with the findings of Krisham et al\(^{11}\) (2009) and McArdle and Renton\(^{12}\) (2005). Pericoronitis could be managed by conservative approaches such as irrigation with antimicrobials, subgingival curettage or antibiotic therapy. Removal of the affected tooth is indicated in the case of recurrent infection\(^{13}\).

Cysts and Tumours: the prevalence of cysts or tumours associated with impacted third molars have been reported\(^{14}\) to range from 0.8 to 6.2%. The affected teeth should be removed in such cases\(^{15}\).

Resorption or caries to adjacent teeth: Patel et al\(^{10}\) found that caries affecting the lower second molar and third molar were the second most frequent indication for lower third molar removal. The aetiology behind this situation is the relative inaccessibility causing food trapping\(^{10}\).
Another reason for early removal of asymptomatic third molars could be the improvement in post-orthodontic treatment retention (decrease of late incisor crowding). In orthodontics, there has been a belief amongst orthodontists that those wisdom teeth will cause tertiary crowding of the teeth, and relapse after the completion of orthodontic treatment. This has led many orthodontists to refer their patients for removal of third molars prior to the commencement of orthodontic treatment, despite the fact that the vast majority of scientific evidence on the role of third molars on anterior crowding has revealed no significant effect.

Risks of third molar extractions
According to Kandasamy et al. (2009), the main risks of third molar extractions are inferior alveolar nerve damage, lingual nerve damage, alveolar osteitis, infection and postoperative complaints (pain, trismus, swelling and generalized malaise), secondary haemorrhage, damage to the adjacent tooth, oro-antral fistulas, maxillary tuberosity fractures and mandibular fractures.

Inferior alveolar and lingual nerve damage: Zuniga (2009) reported that the inferior alveolar nerve (IAN) was the most commonly injured nerve (61.1%), followed by the lingual nerve (LN; 38.8%). In the majority of cases, the damage is temporary and resolves in the first 6 months. There is a wide variation of the reported incidence of the dysesthesia of the inferior alveolar and the lingual nerve following the removal of third molars. Incidence of temporary damage of the IAN or the LN was found by Gargallo-Albiol et al. (2000) to range between 0.278% and 13%. Permanent injury the IAN has
been reported to range between 0.4% and 25% and permanent injury the LN has been reported to range between 0.04% and 0.6%\textsuperscript{19}.

Alveolar osteitis: Also known as (Dry Socket), is a painful complication of dental extraction that appears usually 2-3 days postoperatively. This complication is caused by the disintegration of the blood clot within the socket\textsuperscript{21}. While the prevalence of dry socket was reported to vary from 1% to 5% in routine dental extractions, Daly et al\textsuperscript{22}. (Cochrane Data Base of Systematic Reviews, 2012) indicated that it could be 30% in surgically extracted third molars.

Post-operative infection: The prevalence of post-operative infection following removal of wisdom teeth was reported to be between 0.8 and 4.2% (Kandasamy ,2009)\textsuperscript{17}. Infection to the dentomaxillofacial area could develop to involve deep cervical spaces leading to potentially life-threatening situation. Eftekharian et al. reported a prevalence rate of 31.3%\textsuperscript{23} of deep neck infections and Boscolo-Rizzo et al. found the rate to be 27.9%\textsuperscript{24}.

Temporomandibular joint (TMJ) pain/dysfunction: Huang and Rue (2006) studied the data of 34,491 subjects and concluded that the removal of third molars could be a risk factor for the postoperative onset of temporomandibular joint pain/dysfunction\textsuperscript{25}. Akhter et al. found that third molar removal was significantly associated with TMJ disorder when studying 2,374 First-year university students\textsuperscript{26}.

Opioids dependence: Recently, a study from the US by Harbaugh et al. (2018) suggested that the removal of third molars was associated with higher levels of Future Opioids Persistent use\textsuperscript{27}.
The controversy of prophylactic removal of asymptomatic impacted third molars

There is a consensus\textsuperscript{15} since 1980 that impacted third molars should be removed when they are affected by irreversible pathological changes. In a considerable number of cases, these teeth are asymptomatic, and could potentially remain pathology-free for many years. However, prophylactic extraction of pathology-free impacted teeth has been reported in 18 to 60\% of the extraction cases\textsuperscript{28-30}.

Currently, controversy exists regarding the need for prophylactic removal of asymptomatic third molars. The reasoning from proponents of this procedure include the prevention of pathological changes and decrease in future surgical complications, as the removal of third molars at older age when symptoms arise may be more associated with surgical complications. This was previously the position of the white paper\textsuperscript{31} on wisdom teeth published by the American Association of Oral Maxillofacial surgeons, the leading body representing Oral Maxillofacial Surgeons in the USA. The same arguments are also advocated by highly regarded Australian Oral Maxillofacial Surgeons\textsuperscript{32}, stating that (until there is evidence to the contrary it is recommended that non-functional wisdom teeth are best removed in teenagers and young adults.)

On the other hand, there is mounting evidence supporting the active surveillance of impacted teeth as a more prudent and cost-effective strategy\textsuperscript{33}. Freidman (2007) described the prophylactic extraction of third
molars as a public health hazard\textsuperscript{34} that afflicts tens of thousands of people with lifelong discomfort and disability. The prophylactic removal of impacted third molars was not supported by the American Public Health Association since 2008\textsuperscript{35}. Similarly, in Europe, this approach was not supported by several reports such as the Belgian Health Care Knowledge Centre report\textsuperscript{36} (2012), Scottish National Clinical Guideline report\textsuperscript{37} (1999), Swedish health technology assessment\textsuperscript{38} (2010), The Royal College of Surgeons of England report\textsuperscript{39} (1997) and National Institute for Clinical Excellence (NICE) Guidelines\textsuperscript{40} (2000). In 2012, after an extensive review of the literature, the Cochrane Database Systematic Reviews\textsuperscript{33} concluded that there is insufficient evidence supporting the removal of asymptomatic impacted third molars. Furthermore, the authors described watchful monitoring of these asymptomatic impacted teeth as a more prudent strategy. Another aspect of this controversy is that it often remains unknown if those removed asymptomatic impacted wisdom teeth at a relatively younger age were truly impacted or they were normally developing third molars. Kruger et al.\textsuperscript{41} (2001) studied the status of third molars at age 18 years at 821 participants of the study, as well as the observed changes in their clinical status between ages 18 and 26 years. They concluded that with the exception of horizontally impacted third molars, a substantial proportion of other impaction types do erupt fully between the age of 18 and 26. They also suggested that asymptomatic third molar impaction in late adolescence should not be sufficient grounds for their prophylactic removal.
UK experience with impacted third molars and NICE guidelines

The NICE guidelines (against the prophylactic removal of third molars) has been implemented in the United Kingdom (England) since 2000 and has been followed by dentists in England for the last 18 years. Those Guidelines recommended that the practice of extraction of pathology-free impacted third molars should be discontinued and to limit this practice to patients with evidence of pathology. Those Guidelines are unique to England and no such guidelines exist in Australia.

Prior to the introduction of Third molars guidelines in UK, the number of episodes of hospital admission for third molars removal in the UK was on the rise and increased by one-third between 1988 and 1994. However, after the Royal College of Surgeons of England Guidelines in 1997 and the NICE Guidelines in 2000, the number of third molars related hospitalisations has decreased, with a late slow increase due to rebound effect mostly caused by dental caries at an older age.

While the introduction of the NICE Guidelines on the management of third molars has significantly decreased the number of third molar removals, whether or not these changes have resulted in a net benefit to patients is still a matter for debate. This overall decrease could be attributed to the presence of NICE Guidelines, meanwhile no comparison to other countries without similar guidelines for the same period was ever made.
Management of impacted third molars in Australia

In Australia, the review of Kandasamy et al. (2009) from The University of Western Australia was the first paper to encourage clinicians to re-evaluate their views on prophylactic third molar extractions. George et al. (2011) studied the hospitalization for the surgical extraction of impacted teeth. This study quantified and analysed the number of hospitalizations in Western Australia for a period of 6 years and has shown the significance of associated factors such as Indigenous status, age, gender and private hospital access along with health insurance status. However, it remained unknown whether the rate of impacted teeth removal under GA in Australia was higher than other countries, or whether this practice was prophylactic or related to diseased or symptomatic teeth. From the above the author of this thesis decided to establish a new model of international comparative analysis using the International Classification of Disease to compare 3 health care systems (UK-England, France, and Australia) in regard to hospitalisations for impacted teeth extractions. The study could analyse the impact of the presence of guidelines (England, UK) compared to health care systems without guidelines (France and Australia).
Cost effectiveness of retention of asymptomatic impacted third molars versus removal

The high cost of the prophylactic removal of asymptomatic third molars was first outlined in the United States by Freidman (1977). To contain the cost of third-molar extractions, Freidman (1983) suggested elimination of payment by insurance companies for non-essential extractions and of the related overcharges. Edwards et al. (1999) analysed the cost effectiveness of removal and retention of asymptomatic, disease free lower third molars in the UK health system. They constructed a decision tree model of the outcomes of mandibular third molar retention and removal and entered probability data for possible outcomes into the decision tree. They calculated the cost to the NHS in both strategies. They also asked patients to rate the effect of each outcome. They concluded that Mandibular third molar retention is less costly to the National Health Service (NHS), more effective for the patient and more cost-effective to both parties than removal.

From the above, it was decided that it is essential to analyse the high expenditure of the hospitalisations for impacted teeth removal in Australia and to study the cost effectiveness of removal and retention of asymptomatic, disease free third molars in the Australian health context as no such analysis was ever performed.
Oral Cellulitis

Definition, aetiology and clinical management

Oral cellulitis is a connective deep tissue infection, affecting the oral, sublingual and submandibular regions. It is an infection of the adipose cell tissue located in aponeurotic spaces, surrounded by muscular, vascular, nervous and visceral structures.\(^49\)

This rare condition is mainly derived from dental origin, such as dental caries, periodontal infection or impacted wisdom teeth\(^50,51\). There are no reports in the literature of the exact value of incidence and prevalence of oral cellulitis and deep neck infections\(^52\).

Other causes are peritonsillar or parapharyngeal abscess, mandibular fracture, oral laceration or piercing and submandibular sialadenitis\(^53\). Predisposing known factors are systemic illnesses, malnutrition, alcoholism, compromised immune system\(^51\). Its most serious clinical manifestation is Ludwig’s Angina\(^51,57\), a fatal deep neck cellulitis (current mortality is 8%, down from 50% in the 1940s), which develops by the spread of bacteria through the mylohyoid muscle into submental and para-laryngeal spaces.

Untreated Ludwig’s angina often leads to para-pharyngeal swelling, airway constriction, and asphyxiation\(^57\). The course of treatment for oral cellulitis may include admission to hospital, antibiotics, drainage of existing pus, removal of the cause (i.e. tooth) and tracheotomy in the case of Ludwig’s Angina. The management of oral cellulitis is carried out ideally by an Oral
Surgeon/Oral Maxillofacial Surgeon. In the case of Ludwig’s Angina, critical care physicians may also be required.

A retrospective review by Han et al. (2016) analysed the data of 127 patients treated for Maxillofacial space infection at Peking University School and Hospital of Stomatology. They found that the most common cause was odontogenic infection (57.5%) and the most common space involved was the submandibular space. They found that 16 patients developed life-threatening complications, mainly respiratory obstruction. The percentage of neutrophils upon hospital admission was associated with life-threatening complications.

Similar research by Zhang et al. (2010) at West China Hospital of Stomatology over a five-year period reviewed the data of 212 patients admitted with Maxillofacial infection. Similarly, the most common aetiology was odontogenic infection (56.1%). The submandibular space was also most commonly involved. Fifty-seven patients developed life-threatening complications and six died. A retrospective review of 109 patients admitted between 1997 and 2002 for deep neck infections by Huang (2004) was conducted in Taiwan: 63 patients (34.1%) had systemic diseases, mainly (88.9%) diabetes mellitus. The parapharyngeal space was the most common involved space. Odontogenic infection was the most common cause (53.2%). 30 patients had major complications, and 18 patients received tracheostomies; 3 patients died (mortality rate, 1.6%).

Mathew et al. performed a chart review of patients treated for Maxillofacial Infections from January 2006 to December 2010 in Ludhiana, North India. Diabetes was a predisposing factor as 24.1% of the patients were diabetic.
They found that the most common teeth responsible were the lower wisdom teeth and the most common space involved was also the submandibular space. Twenty patients (14.6%) developed complications. A retrospective study from Taiwan by Yang et al. (2008) of 105 patients with deep neck abscesses showed that old age, underlying systemic diseases and ineffective empiric antibiotics have significant correlation with life-threatening complications. A study from Italy analysed 365 adult patients with deep neck infections and found Diabetes mellitus and multiple deep neck spaces involvement to be the strongest independent predictors of complications: 67 patients (18.4%) developed life-threatening complications and the mortality rate was 0.3%. Motahari et al. (2015) reviewed 815 cases of deep neck infections admitted between 1998 and 2013. While the most common involved space was submandibular space, only 2.7% of the cases had Ludwig’s Angina. Tracheostomy was performed in 5 cases and there was a single mortality. Dental infection and procedures were the main etiological factors. Ludwig. Angina was reported to account for 17.7% of total deep neck infection cases in the study by Gujrathi et al. (2016) followed by submandibular abscess. This study of 270 cases also pointed at diabetes mellitus as the most common associated illness, while the major etiological factor was dental infection.

Das et al (2016) carried out a prospective study on 45 patients with deep neck infections over a period of 1 year between 2008 and 2009. Dental infection was also the commonest etiological factor (64.11%). and diabetes mellitus (26.66%) was also the most common associated illness; 66.6% of participants were from rural areas and the rural distribution was higher.
significantly ($p < 0.01$). Bakir et al (2012) reviewed 173 patients treated for deep neck infection between 2003 and 2010 and they found dental infection to be the most common cause (48.6%), followed by peritonsillar infections (19.7%) and tuberculosis (6.9%). The submandibular space was the most common involved space (26.1%); 95 patients (59.5%) required surgical intervention; and 13.8% of the cases developed life-threatening complications.

It could be concluded from the above studies that dental infections are currently the major aetiology of oral cellulitis world-wide and that Diabetes Mellitus is the most common associated factor.

**Relationship between oral cellulitis and poverty**

Moles (2008) studied the trends of hospitalisations in England between 1997 and 2003 for oral infections requiring drainage of abscess. He found a close association between poverty and dental infections, which increased most among poorer people. Agrawal et al (2008) studied 120 patients in India with deep neck abscess who were managed between 2004 and 2005: 80% had poor oral hygiene and dental infections and extractions were the most common predisposing factor. Ten patients required emergency tracheostomy for airway obstruction. Most of the patients were of low socioeconomic status. A 2014 United States study on longitudinal discharge trends and outcomes after hospitalization for mouth cellulitis and Ludwig’s
angina \textsuperscript{69} found higher rates of admission to hospital at non-white (40%) and found age and insurance status to be factors associated with hospital admissions.

**Oral cellulitis trends in Australia**

In Australia, the review of literature revealed no prior studies on the trends of oral cellulitis hospital admissions or the relationship between oral cellulitis and socioeconomic status. Bridgeman et al. (1995) reviewed 107 cases of acute maxillofacial infections managed at the Royal Melbourne Hospital and the results indicated that many of the patients had sought treatment from dentists in general practice, and that a significant proportion had received sub-optimal management prior to referral\textsuperscript{51}. Uluibau et al. investigated all patients admitted to the Royal Adelaide Hospital with odontogenic infections in calendar year 2003. Forty-eight patients were included in the study. The hospital stay was 3.3 days. Most patients had aggressive surgical treatment with extraction, surgical drainage, high dose intravenous antibiotics and rehydration. No patient died, and all fully recovered\textsuperscript{70}.

**Effect of Indigenous status**

Australia has 3% of its population\textsuperscript{71} self-identifying as Aboriginal and Torres Strait Islanders, who are reported to suffer from low level of dental health\textsuperscript{72} and are generally more likely to be admitted to hospital\textsuperscript{73}. Furthermore, Indigenous populations are 3 times more likely to have diabetes that non-indigenous Australians\textsuperscript{74-76}. Wang et al. estimated that the lifetime risk of
developing diabetes among Aboriginal men is one in two, and among Aboriginal women is two in three\textsuperscript{77}. This review of the literature above has shown the correlation between Diabetes Mellitus and the risk of developing dental infections and there were no prior studies on the relationship between indigenous status and the rate of hospital admissions for oral cellulitis.

From the above studies, it was concluded that oral cellulitis could be used as an indicator of significant dental disease in a society and it was decided to study the association between oral cellulitis and poverty in Western Australia, as well as the effect of age and Indigenous status. Furthermore, the results will be used to determine regions of Western Australia that are predicted to have a high number of the oral cellulitis cases. Finally, similar techniques will be used on a national level to isolate at the highest possible granularity in Australia regions where oral cellulitis risk is high.
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Chapter 3: Materials and Methods:

Study population, Study period, Hospitalisation Data and Principal Diagnosis

In Chapter 3, (International benchmarking of hospitalisations for impacted teeth: a 10-year retrospective study from the United Kingdom, France and Australia), hospitalisation data were collected for the three countries from open access sources for the United Kingdom and France. Data for Western Australia (one state of Australia) were obtained with ethics approval from the Research Ethics Committee of The University of Western Australia approval number RA/4/1/5502, as the data were closed access. In all three jurisdictions data for all those patients with the principal diagnosis of ‘K01: Embedded and Impacted teeth’, as classified by the International Classification of Disease (ICD-10AM) system\(^1\), were included in this study.

Data for analysis were obtained from the Western Australian Hospital Morbidity Data System (HMDS), for 10 financial years, from 1999/2000 to 2008/2009, discharged from any private and public hospital in Western Australia. This state represents just over 10% of the total Australian population and covers nearly 50% of the geographic area of Australia. Population estimates for each year were derived from the Australian Bureau of Statistics.

For England, comparable freely available data for the decade were collected from the hospital episode statistics website\(^2\) for the period from 1999-2000 to 2008-2009.
Population estimates for each year were obtained from the Office for National Statistics, UK.

For France, comparable freely available data for the decade were collected from the hospital episode statistics website\(^3\), derived from the National Information System on Hospitalisation (SNATIH) for the period from 1999 to 2008. All private and public hospitals in mainland France were included. French population estimates for each year were obtained from the French National Institute for Statistics and Economic Studies (INSEE).

In Chapter 4 (Cost effectiveness modelling of a ‘watchful monitoring strategy’ for impacted third molars vs prophylactic removal under GA: an Australian perspective), the base line data used the principal diagnosis of ‘K01: Embedded and Impacted teeth’, as classified by the International Classification of Disease (ICD-10AM) system for Western Australia for the same period as Chapter 3. The analysis also included patient age, insurance status and primary place of residency at the time of hospitalisation. The population data used for the national model Australia-wide was derived from the Australian Bureau of Statistics.

In Chapter 5 (A 10-year retrospective analysis of hospitalisation for oral cellulitis in Australia: the poor suffer at 30 times the rate of the wealthy), hospitalisation and population data for the principal diagnosis ‘K12.2: Cellulitis and Abscess of the Mouth’. were used as in Chapter 3 for Western Australia and England. All hospitalisation data and population in Chapters 3 and 5 were related to England only (i.e. no data were obtained from Scotland, Northern Ireland or wales). Any mention of UK (United Kingdom) in those Chapters should be understood within this context.
Regarding hospitalisations in England, as reported by McArdle and Renton: (Data recorded by HES relates to the number of patients who have been admitted to hospital for either a day-case or in-patient procedure under either GA or IV sedation. In general, patients who have had third molars removed under local anaesthesia on an out-patient basis do not get included in HES data as this activity is recorded as an anonymous out-patient appointment and not as an out-patient surgical activity as with other surgical specialties.)

For Western Australia, gender, age, place of residency (Statistical Local Area [SLA]), indigenous status, type of hospital admitted to, insurance status, and Diagnostic Related Group (DRG) cost estimates for the procedure comprised the data frameset.

In Chapter 6 (Mapping isolation of risk for sporadic conditions: Oral cellulitis in Western Australia), and Chapter 7 (An approach to risk isolation for relatively low-incidence conditions: An Australian national model of oral cellulitis).

All hospitalisation data, population data, gender, age, place of residency, indigenous status, for the principal diagnosis ‘K12.2: Cellulitis and Abscess of the Mouth’ were derived from the same source and used for the same study period as in Chapter 5 for Western Australia. The population data used for the national model Australia-wide in Chapter 7 were derived from the Australian Bureau of Statistics.
Socioeconomic indicators

The Socioeconomic Indexes for Areas (SEIFA) index is the nationally accepted coding for socioeconomic advantage and disadvantage in Australia and is developed by the Australian Bureau of Statistics. SEIFA uses a broad definition of relative socioeconomic disadvantage in terms of community access to resources and the ability to be part of society. SEIFA represents an average of all people living in an area but it does not represent the situation of each person. Thus, SEIFA is only a relative measure, not an absolute measure of socioeconomic disadvantage. There are four indexes under SEIFA concerning different aspects of the socioeconomic conditions of people. For the purposes of this study the SEIFA Index of Relative Socio-Economic Disadvantage (IRSD) was used, as this index focuses primarily on disadvantage. This study has clustered the patients according to SIEFA quintiles from the poorest of the population (Group 1) through to the most advantaged group of the population (Group 5). This Indicator was used in Chapters 4, 5, 6 and 7.

Remoteness

The Accessibility/Remoteness Index of Australia (ARIA) was assigned to each SLA. This index uses distance to populated centres as the basis for quantifying service access and hence remoteness. ARIA categories used are highly accessible (HA); accessible (A); moderately accessible (MA); remote (R) and very remote (VR). This Index was used in Chapter 5.
**Indigenous Status**

Self-reported indigenous status from the HMDS date base and the Australian Bureau of Statistics was used to compare Indigenous to non-Indigenous populations.

**Population based rates analysis and Geographic Information System (GIS)**

Statistical Package for the Social Sciences v21 (SPSS Inc; www.spss.com) was used to produce the required population-based rates. Using Excel v2003 (Microsoft; Redmond, WA, USA), the hospitalisation rate for each population subset derived from the Western Australian morbidity data were applied to the appropriate population subset (such as age, health insurance, Indigenous status, SEIFA) within each SLA. The integrated database was then geo-coded using QGIS (version 2.14) to allow the visualization of the fully integrated data model.

**References**


Section 1: Third molars

Preface:

The next chapter (published article) (Anjrini AA, Kruger E, Tennant M. International benchmarking of hospitalisations for impacted teeth: a 10 year retrospective study from the United Kingdom, France and Australia. British Dental Journal. 2014; 216:E16 1-4), was the first research to show that Australia may have one of the highest rates of third molar removals. It highlights that the global use of the International Classification of Disease could be a valuable tool to compare oral-health-related hospitalisations on an international scale. It also suggests that the NICE guidelines may have prevented the trends of hospitalisations for impacted teeth removal in England from skyrocketing as they have in Australia and France.

This work has received a number of appraisals as detailed in Appendices 1-6, including a BDJ editorial, an article in the West Australian (Daily newspaper) and a UWA 2014 research prize nomination.

The next step of this part was to analyse the economic impact in Australia of surgical removal of impacted third molars for prophylactic/orthodontic retention purposes. Also, this study examined the cost–effectiveness of the proposed watchful monitoring of pathology-free impacted third molars versus their surgical removal. To do so, the numbers and characteristics of hospitalized patients for removal of impacted teeth were estimated, and used to develop a national-level
cost model of both the direct and indirect costs of hospitalisations in Australia. This model was then used to compare both strategies and calculate possible cost savings in the scenario where Australia would adopt guidelines comparable to those of the UK (England). The following chapter (5) (published article) (Anjrini AA, Kruger E, Tennant M. Cost effectiveness modelling of a ‘watchful monitoring strategy’ for impacted third molars vs prophylactic removal under GA: an Australian perspective. British Dental Journal. 2015 July 10;219(1):19-23.), analysed the direct cost, indirect cost and loss of productivity associated with impacted teeth removal on an Australian national level, using a comprehensive novel model which could be used by other comparable jurisdictions. It also suggests that the presence of guidelines in Australia would result in avoiding significant, and arguably unnecessary, costs to society.

This research has attracted significant media coverage Australia-wide as detailed in Appendices 1,7,8 and 9, including an article in ABC Science and a response from the Australian Dental Association (ADA).
Chapter 4 : International benchmarking of hospitalisations for impacted teeth: a 10-year retrospective study from the United Kingdom, France and Australia

Abstract:

Background: The United Kingdom and its national healthcare system represents a unique comparison for many other developed countries (such as Australia and France), as the practice of prophylactic removal of third molars in the United Kingdom has been discouraged for nearly two decades, with clear guidelines issued by the National Institute of Health and Care Excellence (NICE) in 2000 to limit third molar removal only to pathological situations.

No such guidelines exist in Australia or France.

The healthcare systems in UK (England) as for example in France and Australia all use the International Classification of Disease (ICD) coding system for diagnostic categorising of all admissions to hospitals.

Aim: This study rested upon the opportunity of a universal coding system and semi-open access data to complete the first comparative study on an international scale of hospitalisations for removal of impacted teeth (between 99/00 and 08/09).

Results: The international comparison in this study revealed significant differences in rates of admission, with England having rates approximately 5 times less than France, and 7 times less than Australia. These results could be explained by the
implementation of guidelines in the United Kingdom, and the absence of similar guidelines in France and Australia.

**Introduction**

Approximately one fifth of humankind is affected by tooth impaction in some form\(^1\), and in most cases, it is caused by the upper and/or lower third molars\(^2,3\).

Surgical removal of impacted teeth in most developed countries is performed by a trained oral maxillofacial surgeon or oral surgeon (OMFS), and is commonly carried-out under general anaesthesia, in a hospital environment (generally involving one day’s hospitalisation)\(^4\) with post-operative complications in up to 35% of the cases\(^5,6\). These complications can include sensory nerve damage (paraesthesia), alveolar osteitis (dry socket), infection, haemorrhage and pain. Rarer complications include severe trismus, oro-antral fistula, iatrogenic mandibular fracture and complications of general anaesthesia.

It has long been established that impacted teeth need to be removed when they show any sign of associated pathology and/or severe symptoms\(^7\). However, in a considerable percentage of the extraction cases (from 18 to 60%),\(^8-11\) prophylactic extraction of pathology-free impacted teeth has been reported. The reasoning behind this controversial prophylactic procedure is the prevention of pathological changes, decrease in future surgical complications and improvement in post-orthodontic treatment retention (decrease of late incisor crowding). The justification for this prophylactic surgery is disputed and has been debated for many years. In a recent update, and after extensive review of the literature, the Cochrane Database Systematic Reviews\(^8\) concluded that there is insufficient evidence supporting the removal of asymptomatic impacted third molars. Furthermore, the authors...
described watchful monitoring of these asymptomatic impacted teeth as a more prudent strategy.

The possibility of substantially decreasing the number of hospitalisations for impacted tooth extraction led to the introduction of the NICE Guidelines in 2000 in the UK\textsuperscript{12}. They were based mainly on the review of Song et al.\textsuperscript{13} and have been developed by a committee of 24 experts in health economics, epidemiology, public health and surgery. They recommended that the practice of extraction of pathology-free impacted third molars should be discontinued. Similar guidelines have also been established in 1999 by the Scottish Intercollegiate Guidelines Network (SIGN)\textsuperscript{14}. These unique guidelines have been followed by all dentists in the UK for the last 13 years.

This study analysed data from a 10-year period (1999-2009) by examining hospitalisations for impacted teeth removals, and to compare the healthcare systems of France and Australia with that of the United Kingdom. The hypothesis being that in the UK the rates of hospitalisation for impacted teeth are significantly less than that of the other jurisdictions.

**Method**

Hospitalisation data were collected for the three countries from open access sources for the United Kingdom and France. Data for Western Australia (one state of Australia) were obtained with ethics approval from the Research Ethics Committee of The University of Western Australia, as the data were closed access. In all three jurisdictions data for all those patients with the principal diagnosis of
'K01: Embedded and Impacted teeth', as classified by the International Classification of Disease (ICD-10AM) system, were included in this study.

**Western Australia**

Data for analysis were obtained from the Western Australian Hospital Morbidity Data System (HMDS), for 10 financial years, from 1999/2000 to 2008/2009, discharged from any private and public hospital in Western Australia. This state represents just over 10% of the total Australian population and covers nearly 50% of the geographic area of Australia. Population estimates for each year were derived from the Australian Bureau of Statistics.

**United Kingdom**

Comparable freely available data for the decade were collected from the hospital episode statistics website (www.hesonline.nhs.uk) for the period from 1999-2000 to 2008-2009. All NHS trusts in England were included. The data also included private patients treated in NHS hospitals, patients resident outside of England but receiving care delivered by treatment centres (including those in the independent sector) funded by the NHS. No reliable data source was available for patients treated fully by the independent sector. As only 10% of population is covered by private insurance in the UK, their exclusion would not have had a significant effect on our comparative study. Population estimates for each year were obtained from the Office for National Statistics, UK.
France

Comparable freely available data for the decade were collected from the hospital episode statistics website www.atih.sante.fr\textsuperscript{18}, derived from the National Information System on Hospitalisation (SNATIH) for the period from 1999 to 2008. All private and public hospitals in mainland France were included. French population estimates for each year were obtained from the French National Institute for Statistics and Economic Studies (INSEE).

Recording periods

It is noted that there is a slight difference in recording periods as a financial year in the UK is from 1 April to 31 March, in France from 1 January to 31 December, while in Australia a financial year is from 1 July to 30 June. However, it is not expected that this marginal effect (over a decade of data) will have any effect on the data. If it does, the level of effect would be at best minimal relative to the results of the study.

To establish a quantitative comparison between three differently sized populations, hospitalisation rates per 100,000 population/year were calculated (total population approximately 50 million), France (approximately 62 million) and Western Australia (approximately 2 million). These rates were not age standardised. All data were collated and analysed with Microsoft Excel (version 2003 Microsoft Corporation Redmont USA).
Results

Overall numbers

There was a total of 88,286 patients hospitalised in Western Australia for removal of impacted/embedded teeth during the 10-year period 1999-2000 to 2008-2009. The number of patients admitted to hospital for this condition per year increased by 81% over the study period (Fig. 1, Table 1), with an annual increase of between 1.2% and 23% per annum. In France, 1,834,613 patients were hospitalised for the same condition over the same period and the annual number increased by 36% over the decade. Most of the increase (32%) occurred between 1999 and 2005. In England 352,287 patients were hospitalised for impacted/embedded teeth. The number of patients admitted per year decreased by 20% over the study period. There was a sharp decrease of 61% between 1999/2000 and 2003/2004 followed by slow increase of 33% between 2003/2004 and 2008/2009 (Fig. 1, Table 1).
Table 1  Admissions and rate per 100,000 population for impacted/embedded teeth in England, France and Western Australia for the period 1999/2000–2008/2009

<table>
<thead>
<tr>
<th>Year</th>
<th>England¹</th>
<th>Rate²</th>
<th>France</th>
<th>Rate²</th>
<th>Western Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999/00</td>
<td>47,679</td>
<td>97.2</td>
<td>150,496</td>
<td>257.2</td>
<td>6,347</td>
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<tr>
<td>2000/01</td>
<td>37,435</td>
<td>76</td>
<td>156,145</td>
<td>265.2</td>
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<tr>
<td>2001/02</td>
<td>31,658</td>
<td>64</td>
<td>169,511</td>
<td>286</td>
<td>8,121</td>
</tr>
<tr>
<td>2002/03</td>
<td>31,028</td>
<td>62.4</td>
<td>176,405</td>
<td>295.5</td>
<td>8,627</td>
</tr>
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<td>2003/04</td>
<td>29,487</td>
<td>59.1</td>
<td>185,536</td>
<td>308.7</td>
<td>8,731</td>
</tr>
<tr>
<td>2004/05</td>
<td>30,696</td>
<td>61.2</td>
<td>192,693</td>
<td>318.4</td>
<td>9,019</td>
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<td>2005/06</td>
<td>32,539</td>
<td>64.4</td>
<td>198,565</td>
<td>325.7</td>
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<td>2006/07</td>
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<td>64.9</td>
<td>198,521</td>
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<td>2007/08</td>
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<td>201,636</td>
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<tr>
<td>2008/09</td>
<td>39,495</td>
<td>76.7</td>
<td>205,105</td>
<td>330.1</td>
<td>11,491</td>
</tr>
</tbody>
</table>

¹Re-used with permission from the NHS Information Centre. All rights reserved; ²Rate of admissions per 100,000 population
Fig. 1 Total number of admissions for impacted/embedded teeth in Western Australia, France and England for the period 1999/2000–2008/2009
Rates of hospitalisation

A comparison of rates of hospital admissions for impacted teeth per 100,000 population in England, France and Western Australia is depicted in Figure 2. The rate changes over the period followed the same trends as the total number of admissions (Fig. 1). In 2004/2005 the rate for England was 61, France was 318 and Western Australia 455. This indicates that rates of admissions in Western Australia were significantly higher (740%) than England and (42%) higher than France. While on the other hand, in France the rates were significantly (520%) higher than England. Toward the end of the study period (2008/2009), this difference remains substantial with Western Australian rates 690% higher than England and 60% higher than France. Similarly, rates in France were 430% higher than England.

Fig. 2 Rate of admissions for impacted/embedded teeth per 100,000 population in Western Australia, France and England for the period 1999/2000–2008/2009
DISCUSSION

Removal of impacted teeth under general anaesthesia offers the possibility of extracting multiple teeth at one admission, less discomfort to the patient, and thus the intention of providing a more cost-effective and efficient service, and also allows more visibility to the oral surgeon.

The recoding of hospital admissions for these procedures also offers the opportunity to closely monitor the trends of this practice over time, in a given healthcare system and on a large scale. This is particularly important when considering that a considerable percentage of the overall impacted teeth removals are performed as an in-office procedure, which is very difficult to monitor in a statistically reliable way. The healthcare systems in the UK, France and Australia all use the International Code of Diagnostics (ICD) coding system for diagnostic categorising of all admissions to hospitals. As the same coding system is used for hospitalisations for removal of impacted/embedded teeth in those three countries, it was possible to draw the first comparative study on an international scale regarding hospitalisations for removal of impacted teeth (mainly third molars).

The international comparisons in this study revealed significant differences in rates of admission for impacted teeth, which could be explained by the implementation of NICE guidelines in the United Kingdom (England) and the absence of similar guidelines in France and Australia. As these countries are very comparable in terms of most factors affecting third molar pathology and the way dental services are delivered, other contributing factors such as insurance policies, cost of
treatment and the number of oral maxillofacial surgeons (OMF) and stomatologists – in the case of France – could not alone explain such substantial differences. Furthermore, those contributing factors could be closely related, as in the case of insurance policies and cost, to the presence/absence of guidelines.

Interestingly, despite the fact that the vast majority of the research done on the role of third molars on anterior crowding revealed no significant effect,\textsuperscript{19–22} many OMF surgeons and orthodontists still believe that the erupting third molars are capable of pushing the anterior teeth forward, causing anterior crowding.\textsuperscript{23} As removal of third molars has been performed in order to prevent abnormal orthodontic conditions,\textsuperscript{24–26} it is likely that this purpose would be responsible for a considerable percentage of the cases in France and Australia.

Western Australia is the largest State of Australia with a population of around 2 million, which is a reasonably representative sample of the Australian healthcare system. The practice of hospitalisation for removal of impacted teeth has previously been analysed\textsuperscript{27–29} in Western Australia and revealed the high related expenditure and the significance of associated factors such as indigenous status, age, gender and private hospital access along with insurance status. This study has clearly shown that the rates of hospitalisations for impacted teeth removal in Western Australia are substantially higher than the rates in UK and higher (but to a lesser extent) than the rates in France. These findings should be of interest to both healthcare authorities, and insurance companies, as it presents a significant economic impact, and also highlights the possibility of some unnecessary hospitalisations, thereby further burdening the health system.

The impact of guidelines on the practice of third molar extraction in the UK has been reviewed by Renton et al.\textsuperscript{30} and by McArdle and Renton\textsuperscript{31}. Between 1988
and 1994 the number of episodes in the UK was on the rise and increased by one-third\textsuperscript{11}. An overall decrease of numbers of third-molar-related hospital admissions was observed since the RCS guidelines were introduced in 1997, with a late slow increase since 2005, which has been attributed to rebound effect mostly caused by dental caries at an older age\textsuperscript{30,31}. Those findings were consistent with the present analysis of the trends in England between 1999 and 2008.

The first reports on the third molar removal controversy in UK were published by Brickely and Shepherd and others,\textsuperscript{32-38} between 1993 and 1996. Their work, as well as the extensive media coverage on this issue in the UK\textsuperscript{30} has led to the development of RCS\textsuperscript{39} Guidelines in 1997 followed by SIGN Guidelines in 1999.

The first review of Song et al.\textsuperscript{40} (1997) and the subsequent commentary by Shepard\textsuperscript{41} (1998), together with the final report of Song et al.\textsuperscript{13} (2000) have been the basis upon which the National Institute of Health and Clinical Excellence (NICE) issued their guidelines regarding third molar management in 2000\textsuperscript{12}. They recommended that the practice of extraction of pathology-free impacted third molars should be discontinued and to limit this practice to patients with evidence of pathology. However, they only recommended a standard routine programme of dental care for pathology-free impacted third molars. This was recently criticised by Mansoor et al.\textsuperscript{41}, citing the need for periodical panoramic radiography examination of impacted teeth, even in the absence of symptoms and signs. Furthermore, in view of their reported increase of caries to adjacent teeth, a more focused surveillance of mandibular third molars has been suggested by Renton et al.\textsuperscript{30}. Those recommendations are consistent with the strategy of watchful monitoring of pathology-free impacted teeth, prescribed by the Cochrane Database Systematic Reviews.\textsuperscript{8}
Conclusion

The key findings from the present study were that Australia may have a high rate of third molar removals under GA, as compared to other developed countries. The study outlines that the global use of the International Classification of Disease could be a valuable tool to compare oral-health-related hospitalisations on an international scale. It also suggests that the NICE guidelines may have prevented the trends of hospitalisations for impacted teeth removal in England from increasing, as they have in Australia and France. These findings raise the potential that the presence of good-quality clinical guidelines for dental procedures, especially those requiring access to high cost health system facilities and treatment, has the potential long-term opportunity to more efficiently, and cost effectively, manage care and target it to those most in need.
References


Chapter 5: Cost effectiveness modelling of a ‘watchful monitoring strategy' for impacted third molars vs prophylactic removal under GA: an Australian perspective

Abstract

Objective: To develop a national level cost model of both the direct and indirect costs of hospitalisations for impacted teeth in Australia. This model will then be used to compare a watchful monitoring strategy for impacted third molars versus prophylactic removal under GA, and calculate possible cost savings in the scenario where Australia would adopt guidelines comparable to the UK.

Methods: Western Australian real hospitalisation data for impacted/embedded teeth removal for 2008/2009 were extrapolated into a national, Australian-wide cost-distribution model for removal strategy. The components of a watchful monitoring strategy were calculated over a one-year, and 20-year period. Cost estimates for both strategies were then compared.

Results: The estimated number of hospitalisations for impacted teeth in Australia in 2008/2009 for the age group 15–34 years was 97,949. The estimated average annual direct cost was $350 million, the indirect cost was $181 million and total cost was $531 million. Individual cost of the watchful monitoring strategy over 20 years was $1,077, with an annual estimated cost of $53. The proposed guidelines would lead to an annual figure of 83,850 individuals avoiding hospitalisation and
shifting to watchful monitoring strategy, and an annual reduction of costs ranging between $420–513 million.

**Conclusion:** With no evidence to support the prophylactic removal of asymptomatic wisdom teeth, a proposed watchful monitoring strategy is a more cost-effective alternative in the Australian context.

**INTRODUCTION**

The prevalence of third molar impaction in the general population is high, and has been reported to range between 18–68%.

A global debate over the management strategy for impacted, symptomless third molars is continuing. One approach is to prophylactically remove them to prevent crowding of lower incisors, as well as to prevent possible pathologies such as caries of adjacent teeth, periodontal disease, cyst formation and infection, abscess or cellulitis. While this approach is supported by the American Association of Oral and Maxillofacial Surgeons, the prophylactic removal of impacted third molars was not supported by the American Public Health Association since 2008. Similarly, in Europe, this approach was not supported by several reports such as Belgian Healthcare Knowledge Centre report (2012), Scottish National Clinical Guideline report (1999), Swedish health technology assessment (2010), Royal College of Surgeons of England report (1997) and National Institute for Clinical Excellence (NICE) guidelines (2000). At the other end of the spectrum of the debate is the strategy to closely monitor those impacted teeth over the rest of the patient’s life (watchful monitoring). The argument behind this approach is mainly to prevent complications of extractions, such as pain, bleeding, swelling, dry socket, trismus, damage to the nerve and to the temporomandibular joint, with the rate of
complications reported to be between 4.6%\textsuperscript{25} and 21%\textsuperscript{26}. In comparing these two models, the cost effectiveness of each strategy is an important factor in the design of healthcare policies and therapeutic guidelines.

In Australia, impacted teeth (mostly third molars) are usually removed under general anaesthesia by an oral maxillofacial surgeon. This procedure is associated with insured individuals and at a relatively young age\textsuperscript{27}. Furthermore, it has been recently reported\textsuperscript{28} that the rates of hospitalisations for impacted teeth were one of the highest in the world, with Western Australia having rates of hospitalisation almost 7-times (690\%) that of England, where third molar removals are restricted to symptomatic cases, since 2000\textsuperscript{15}. Those findings suggest that about 85\% of third molar removals in Australia are likely to be prophylactic\textsuperscript{28}.

The hypothesis of this study was that, in the Australian context, the direct and indirect costs associated with third molar removal in hospital would be substantially higher than the costs associated with the proposed watchful monitoring strategy. The aim was to estimate the number and characteristics of hospitalised patients for removal of impacted teeth, and use this to develop a national level cost model of both the direct and indirect costs of hospitalisations in Australia. This model will then be used to compare both strategies, and calculate possible cost savings in the scenario where Australia would adopt guidelines comparable to the UK.

METHOD

Baseline data
The base data were obtained from the Western Australian Hospital Morbidity Data System under appropriate ethical data release. Ethics approval for this study was obtained from the Human Ethics Committee of The University of Western Australia.

Every episode of discharge from all private and public hospitals in Western Australia for the financial year 2008/2009 for removal of impacted or embedded teeth as the principal oral condition, as classified by the International Classification of Diseases, Tenth Revision, Australian Modification (ICD-10-AM), was included in the dataset.\textsuperscript{29} The analysis also included patient age, insurance status and primary place of residency at the time of hospitalisation. All dollars presented in this study are Australian dollars, and at a fixed cost of living as at 2009, unless otherwise stated.

**National model based on WA**

**Rates calculation**

The rate calculations for Western Australian Hospitalisation were then measured using population data obtained from the Australian Bureau of Statistics 2006 Census. Age, insurance status and socioeconomic indexes for areas (SEIFA) category were included as risk indicators. These driving variables are strongly linked to third molar extraction rates in Australia\textsuperscript{27}. It is noted that the 2006 census data were chosen to be closest to the 2008/2009 hospitalisation base data. The age variable was divided into four sub-sets: 15–19, 20–24, 25–29 and 30–34 years. As those age groups comprise 80% of all cases reported, ages <14 years and >35 years were not included as the small numbers would skew the modelling. The insurance status variable has two subsets: insured and non-insured. SEIFA is the nationally accepted coding for socioeconomic advantage and disadvantage in
Australia. The five categories (subsets) for SEIFA are: most disadvantaged, above average disadvantaged, average disadvantaged, below average disadvantaged and least disadvantaged. A total of 40 distinct rates of third molar extraction were computed dependent on the mix of the variables sub-sets. SPSS version 21 was used to produce the required population-based rates.

Distribution of model nationally

Australia is divided by the Australian Bureau of Statistics into 1,353 non-overlapping/no-gaps statistical local areas (SLAs). The population data across each of the 1,353 SLAs were distributed by age, health insurance status and SEIFA. Using Microsoft Excel (2003), the hospitalisation rate for each population subset derived from the Western Australian morbidity data was applied across Australia to the appropriate population subset (age, health insurance status, SEIFA) within each statistical local area.

Table 1 The number, proportion and cost of modelled cases of third molar extraction per State per annum of Australia

<table>
<thead>
<tr>
<th>State</th>
<th>Cases</th>
<th>Cost pa ($ millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cases</td>
<td>Insured</td>
</tr>
<tr>
<td>NSW</td>
<td>25,516</td>
<td>6,402</td>
</tr>
<tr>
<td>VIC</td>
<td>20,195</td>
<td>5,069</td>
</tr>
<tr>
<td>QLD</td>
<td>15,172</td>
<td>3,808</td>
</tr>
<tr>
<td>SA</td>
<td>5,868</td>
<td>1,469</td>
</tr>
<tr>
<td>WA</td>
<td>7,789</td>
<td>1,949</td>
</tr>
<tr>
<td>TAS</td>
<td>1,747</td>
<td>436</td>
</tr>
<tr>
<td>NT</td>
<td>527</td>
<td>134</td>
</tr>
<tr>
<td>ACT</td>
<td>1,493</td>
<td>375</td>
</tr>
<tr>
<td>Grand total</td>
<td>78,307</td>
<td>19,642</td>
</tr>
</tbody>
</table>
Accessibility

The degree of remoteness of each statistical local area was obtained from the Australian Bureau of Statistics website\textsuperscript{30} using the Australian Standard Geographical Classification (ASGC) Remoteness Area Correspondences, 2006. The ASGC classification divides Australia by remoteness into five groups: major cities Australia (R1), inner regional Australia (R2), outer regional Australia (R3), remote Australia (R4) and very remote Australia (R5). For SLAs that fall into two categories of ASGC classification, the group with higher percentage was chosen.

Table 2 the number, proportion and cost of third molar extraction cases per geographical area of Australia per annum

<table>
<thead>
<tr>
<th>Geographic area</th>
<th>Hospitalisations</th>
<th>%</th>
<th>Cost pa ($ millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major cities of Australia</td>
<td>59,432</td>
<td>60.7</td>
<td>316</td>
</tr>
<tr>
<td>Inner regional Australia</td>
<td>23,914</td>
<td>24.4</td>
<td>128</td>
</tr>
<tr>
<td>Outer regional Australia</td>
<td>10,734</td>
<td>11.0</td>
<td>62</td>
</tr>
<tr>
<td>Remote Australia</td>
<td>2,764</td>
<td>2.8</td>
<td>18</td>
</tr>
<tr>
<td>Very remote Australia</td>
<td>1,105</td>
<td>1.1</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>97,949</td>
<td>100</td>
<td>532</td>
</tr>
</tbody>
</table>

Direct costs

The Australian Refined Diagnosis Related Group (AR-DRG) version 5.1 was used to calculate the direct cost. Estimated cost of care was determined for each episode using the national standard diagnostic related group (DRG) average price. For insured individuals, out of pocket additional hospital costs were added. Three estimated levels (low, medium and high) of this additional cost were calculated based on the data from the Australian Institute of Health and Welfare.\textsuperscript{31}
Indirect cost

Loss of productivity (absenteeism) was calculated using average sick leave days associated with wisdom teeth removal under general anaesthesia, which is 5.7 days, as reported by Edwards et al.\textsuperscript{32} The average cost to the economy per day was calculated as average day earning, which is 20\% of average weekly earnings estimated by the Australian Bureau of Statistics in November 2013 at $1498.70.\textsuperscript{33}

Most hospitalisations for impacted teeth are performed in the major cities and patients living in R2, R3, R4 and R5 need to travel to hospital. To account for travelling days, an extra one, two and three days were allocated for patients living in R3, R4 and R5 respectively. An estimated cost for transport was allocated to each of the five geographic groups (R1 to R5). Travel cost was estimated on three levels (low, medium and high) to account for different methods of transport.

Cost calculation of watchful monitoring strategy

The watchful monitoring strategy included a proposed plan of active surveillance over time of retained asymptomatic impacted third molars. This plan included clinical examination and panoramic radiography every two years.\textsuperscript{34} The retention period extends for the life of the patient until wisdom teeth become symptomatic and removed, or until they fully erupt. However, to establish a cost comparison over a reasonable period, the proposed retention period included in this study was 20 years,\textsuperscript{35} considering initial examination at the age of 15 as a high proportion of hospitalisations for impacted teeth in Australia starts at that age.\textsuperscript{36}

The average cost of comprehensive oral examination (Australia wide) was retrieved from the Australian Dental Association Fees survey for 2012.\textsuperscript{37} Panoramic imaging
(bulk billed) cost was retrieved from Medicare Australia Benefits Schedule as at August 2014. A scenario of Australian rates dropping to UK rates was analysed. Although an Orthopantomograph (OPG) was included at every clinical visit, it would be expected that a clinician would show judgement in this decision.

However, for the sake of the modelling the maximum one per clinical examination was taken. Indirect cost for watchful monitoring strategy was not included in this study, as it was assumed it will be part of regular care by the most convenient dentist, without significant travel costs or loss of productivity.

RESULTS

Direct and indirect cost of hospitalisations

Number of cases

The estimated number of hospitalisations for impacted teeth in Australia, in 2008/2009 for the age group 15–34 years was 97,949. Insured patients accounted for 78,307 (80%) and non-insured patients for 19,642 (20%). The distribution over the States and Territories of Australia is shown in Table 1. The distribution of hospitalisation cases over the five remoteness area groups is shown in Table 2, with group R1, (major cities of Australia n = 59,433) and R2 (inner regional Australia n = 23,915) accounting for 85% of the hospitalisations.
Direct cost

The annual direct cost of hospitalisations, excluding out of pocket cost, was estimated to be $259 million with individual DRG cost of $2644 for each hospitalisation. Approximately 85% of this amount ($207 million) was paid by insured patients. Out of pocket cost, paid to hospitals by insured patients, was estimated to range between $58–156 million, with a medium calculation of $91 million. In total, the direct cost of hospitalisations ranged between $317–415 million, with the medium calculation being $350 million.

Indirect costs

Indirect cost (absenteeism and transport) was estimated to be $178 million (low), $181 million (medium) and $183 million (high) with average individual costs of $1850. The total combined direct and indirect cost would range between $496 million (low), $531 million (medium) and $599 million (high). These cost figures are related to age groups 15–34 years only, which represents 80% of hospitalisations. Table 3 summarises the individual average cost of tooth removal under general anaesthesia.
Individual cost of watchful monitoring strategy

The estimated individual cost for 20 years of watchful monitoring, which includes 10 clinical examinations ($60.3) and panoramic radiographs ($47.4), was $1077 (Table 4). Therefore, the estimated annualised cost (noting that the recommended examinations was every two years) was $53.8, which is approximately 1% of the estimated total cost of single episode of removal.

Table 3. Average individual cost (Australian dollars) of third molar removal under GA

<table>
<thead>
<tr>
<th></th>
<th>Insured</th>
<th>Non-insured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct hospitalisation cost</td>
<td>2,644</td>
<td>2,644</td>
</tr>
<tr>
<td>Additional out of pocket direct cost</td>
<td>1,170</td>
<td>N/A</td>
</tr>
<tr>
<td>Indirect cost (Absenteeism + Travel)</td>
<td>1,850</td>
<td>1,850</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5,664</td>
<td>4,494</td>
</tr>
</tbody>
</table>

Table 4. Average individual cost (Australian dollars) of third molar watchful monitoring strategy.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Comprehensive oral examination</td>
<td>60.3</td>
</tr>
<tr>
<td>Orthopantomogram</td>
<td>47.4</td>
</tr>
<tr>
<td>Combined cost of monitoring protocol</td>
<td>107.7</td>
</tr>
<tr>
<td>Cost for ten monitoring sessions (20 y)</td>
<td>1,077</td>
</tr>
</tbody>
</table>

Cost implications for the adoption of watchful monitoring

The scenario of Australian rates of hospitalisation dropping to UK rates following the adoption of the watchful monitoring strategy revealed a possible reduction by 85%. The annual number of 83,850 individuals avoiding hospitalisation, and
shifting to a watchful monitoring strategy and an annual reduction of costs ranging between $420–513 million. This was dependent on the scenario of the calculation and inclusive of the ongoing watchful monitoring of those patients that fell outside the criteria for extraction.

**DISCUSSION**

Dentists are often faced with the situation of asymptomatic, disease-free impacted teeth, and are usually tempted to provide treatment for those cases. The decision between two treatment options, that is, prophylactic removal or retention, is left to the individual judgements of dentists, with the exception of the UK. There, the practice of prophylactic removal of third molars has been discouraged for nearly two decades, with clear guidelines issued by NICE in 2000 to limit third molar removal to only pathological situations, such as untreatable tooth decay, abscesses, cysts or tumours, disease of the tissues around the tooth and if the tooth is in the way of other surgery.\(^{24}\)

The prophylactic removal of impacted wisdom teeth has been traditionally advocated in Australia and the widely provided argument was to avoid dental infections and oral cellulitis, especially at older age.\(^{39}\) It would be expected, following this reasoning, that the rates of submandibular cellulitis would be higher in the UK, which has 85% less wisdom teeth removals.\(^{28}\) It has been recently shown that this is not the case, and the actual rates of oral cellulitis in Australia were significantly higher than in the UK for the period between 1999 and 2008.\(^{40}\)
One reason for this attitude in Australia might be that oral maxillofacial surgery is considered predominantly a dental speciality dealing mainly with pathology in the jaws and related structures and the removal of impacted wisdom teeth, which constitute a major percentage of oral maxillofacial work in Australia. This is not necessarily the case in the UK, where oral maxillofacial surgery is considered more of a medical speciality with a wider scope of practice extending to pathology in the face and neck area.

Complications arise such as post-operative infection, nerve injury/paraesthesia in the case of removal strategy, as well as the scenario in which a disease-free wisdom tooth becomes symptomatic during the watchful monitoring period and needs removal. However, a previously published study by Edwards et al. in the UK used probability data for possible outcomes of both strategies which were entered into a decision tree. They concluded that, in the UK, mandibular third molar retention is less costly to the NHS, more effective for the patient and more cost-effective to both parties than removal.

One limitation of this study may be the accuracy of the indirect cost estimates regarding absenteeism. Absenteeism measurement is affected by different patient factors, such as being unemployed or a student, and this information was not available in the database for each case of hospitalisation. However, the Australian unemployment rate is approximately 6% and the majority of individuals hospitalised (80%) have private health insurance, which is highly correlated to having employment. As for the age group 15–19, the Australian Bureau of Statistics states that only 42% are employed. However, it is implied that a parent or carer, who is most likely employed, will take an absence from work and stay with their child.
The results of this current research reveal that the controversial practice of prophylactic asymptomatic wisdom teeth removal is responsible for an extremely high expenditure by Medicare, insurance companies and individuals, as well as a considerable loss of productivity. An alternative watchful monitoring strategy was shown to be more cost effective with minimal annual cost.

The UK experience with NICE guidelines since 2000 has been evaluated and although the overall number of removal of third molar episodes has decreased significantly, there has been a slow increase in the number of episodes since 2005, mostly due to caries to adjacent teeth and at an older age. A criticism of NICE guidelines by Mansoor et al. in 2014 was that the recommended ‘standard routine programme of dental care’ for asymptomatic, disease-free impacted third molars, is not straightforward when it comes to radiographic examination, as bitewing and periapical radiographs are usually not helpful for radiographic examination of wisdom teeth. A more focused surveillance for adjacent caries was also recommended by Renton et al. The proposed watchful monitoring strategy, including an OPG every two years and a thorough clinical examination for periodontal pockets and caries would be an improved version of the NICE prescription.

In conclusion, with no evidence to support or refute the prophylactic removal of asymptomatic wisdom teeth, proposed watchful monitoring strategy is a more cost-effective alternative in the Australian context.
References


Section 2: Oral cellulitis

Preface

This part contains three chapters (6-8) which study Hospitalisations for Oral Cellulitis in Australia.

The first part, Chapter 6, was published in the Faculty Dental Journal, Royal College of Surgeons of England: Anjrini AA, Kruger E, Tennant M. A 10-year retrospective analysis of hospitalisation for oral cellulitis in Australia: the poor suffer at 30 times the rate of the wealthy. Faculty Dent J. Volume 5, Number 1, January 2014, pp. 8-13(6)

It is a retrospective analysis of hospitalization data for the 10-year period for oral cellulitis. The study demonstrates how this rare, sporadic condition affects the poorest groups of the population as much as 30 times that of the wealthy. It also shows the impact of age, indigenous status and includes a comparison with UK for the same period.

Secondly, in Chapter 7, we used the results of Chapter 6 were used to develop a risk location indicator and apply GIS models to determine regions of Western Australia that are predicted to have a high number of the oral cellulitis cases. This type of predictive model can assist in focusing primary health resource to areas of
risk and thereby reduce the substantial costs, and risks, associated with treating this condition.

This Chapter is currently under review (submitted but not yet accepted) by the Asia Pacific Journal of Health Management.

Finally, in the third part (Chapter 8) the aim was to establish a risk indicator, comparable to the indicator developed in Chapter 6, which could be applicable on a national level to isolate at relatively high resolution in Australia regions where oral cellulitis risk is high using GIS. The distribution of the population at risk of oral cellulitis was studied with the effect of distance from the centre of the capital city of each state of Australia.

This Chapter is currently under review (submitted but not yet accepted) by the International Journal of Health Policy and Management.
Chapter 6: A 10-year retrospective analysis of hospitalisation for oral cellulitis in Australia: the poor suffer at 30 times the rate of the wealthy

Abstract

The aim of this study was to investigate the trends of hospitalisation for cellulitis in Western Australia. There was a strong association between socioeconomic status and rate of cellulitis, with the most disadvantaged quintile of the population (1.7% of residents) accounting for 34% of cellulitis cases. Aboriginal and Torres Strait Islander people were almost 7 times over-represented, compared with non-Indigenous Western Australians.

Introduction

Cellulitis of the floor of the mouth and submandibular region is a rare condition that mostly (80%) develops as a result of caries-pulpal necrosis and/or periodontitis, pericoronitis associated with unerupted and partially erupted teeth\(^1\)\(^-\)\(^3\). The most serious clinical presentation of cellulitis is Ludwig’s Angina, a potentially fatal, rapidly spreading soft-tissue infection with a tendency to cause oedema, distortion, and obstruction of the airway\(^3\)\(^,\)\(^4\). In most cases of cellulitis hospital admission is required to drain pus and remove the cause. Cellulitis of the mouth and submandibular region can be used as an indicator of significant dental disease in a society. As a measure of the extreme level of dental disease at a population level, it can provide indicators of disease burden and the general dental service uptake,
as good general dental health will mitigate the risk factors that can lead to cellulitis. Against this backdrop, an analysis of the incidence and distribution of mouth and submandibular cellulitis (for the rest of this study described as cellulitis) is a good measure of a community’s global oral health. Western Australia is the largest geographic state in Australia, with a total population approaching 2 million people. Of this total population about 1.6 million live in the major capital city, Perth. Western Australia is a relatively wealthy community with a high GDP and a strong public health system. Safety net dental services for the poor augment a strong private general dental network. More than 80% of all dental services are provided in the private sector on a fee-for-service basis. People in poverty can access government subsidised care. The State also provides universal coverage for school-age children. With this robust service model, it would be expected that the level of cellulitis would be low with respect to comparable situations and the rate would be expected to be stable over time. The aim of this study was to investigate the trends of hospitalisation for cellulitis in Western Australia.

**Method**

**Hospitalisation data**

De-identified clustered data were obtained from the state-wide hospital morbidity data system under the ethics approval of The University of Western Australia. Gender, age, place of residency (Statistical Local Area [SLA]), indigenous status, type of hospital admitted to, insurance status, and Diagnostic Related Group (DRG) cost estimates for the procedure comprised the data frameset. Data for analysis were obtained from Western Australian Hospital Morbidity Data System (HMDS) for 10 financial years, from 1999–2000 to 2008–2009. The principal diagnosis,
classified by the international Classification of disease (ICD-10AM) system,\textsuperscript{5} was obtained for every patient diagnosed with the condition ‘K12.2: Cellulitis and Abscess of the Mouth’ and discharged from any private and public hospital in Western Australia during the study period. Code K12.2 is mainly applicable to cellulitis of floor of mouth and submandibular abscess, while other jaw cellulitis cases are classified under code L03.211 and were not included in this study, as they do not correlate with the fatal condition (Ludwig Angina).

**Population data**

Population data were derived from 2006 census data collected by the Australian Bureau of Statistics. It was extracted from the online census data clustered by SLA to match the clustering of the hospitalisation data\textsuperscript{6}.

**Socioeconomic indicators**

The Socioeconomic Indexes for Areas (SEIFA) index is the nationally accepted coding for socioeconomic advantage and disadvantage in Australia and is developed by the Australian Bureau of Statistics. SEIFA uses a broad definition of relative socioeconomic disadvantage in terms of community access to resources and the ability to be part of society. SEIFA represents an average of all people living in an area but it does not represent the situation of each person. Thus, SEIFA is only a relative measure, not an absolute measure of socioeconomic disadvantage. There are four indexes under SEIFA concerning different aspects of the socioeconomic conditions of people. For the purposes of this study the SEIFA Index of Relative Socio-Economic Disadvantage (IRSD) was used, as this index focuses primarily on disadvantage\textsuperscript{7}. This study has clustered the patients
according to SIEFA quintiles from the poorest of the population (Group 1) through to the most advantaged group of the population (Group 5).

**Remoteness**

The Accessibility/Remoteness Index of Australia (ARIA) was assigned to each SLA. This index uses distance to populated centres as the basis for quantifying service access and hence remoteness. ARIA categories used are highly accessible (HA); accessible (A); moderately accessible (MA); remote (R) and very remote (VR).8

**England**

Comparable data from England for the decade were collected from freely available hospital episode statistics website9 for the period from 1999–2000 to 2008–2009. All NHS trusts in England were included. The data also included private patients treated in NHS hospitals, patients resident outside of England and care delivered by treatment centres (including those in the independent sector) funded by the NHS. England’s population estimates for each year were obtained from The Office for National Statistics, UK. Note that there is a slight difference in recording periods as the financial year in UK is from 1 April to 31 March, while in Australia it is from 1 July to 30 June; however, it is not expected that this marginal effect (over a decade of data) will have any effect on the data. If it does, the level of effect would be at best minimal relative to the results of the study.
Results

General descriptive statistics:

There was a total of 762 patients hospitalised in Western Australia for cellulitis during the 10-year period 1999–2000 to 2008–2009. More males (59.8 %) than females (40.2%) were hospitalised. The mean length of stay in hospital was 3.1 days (SD=3.7) and the average DRG cost estimate was $6,997(SD=$17,033). The number of patients admitted to hospital for this condition per year almost doubled over the study period from 1999–2000 to 2008–2009, with the peak age group being between 20–35 years old (Figure 1).

Figure 1: The age profile of cases of oral cellulitis in Western Australia over the decade 1999-2009.

Remoteness of residency and socioeconomics
Remote and very remote-dwelling people made up some 14.5% of the total cases of hospitalisation for oral cellulitis, while only representing 7.1% of the population. A consistent trend was not evident in remoteness, although remote area-dwelling people had the highest rates of hospitalisation (Figure 2). The analysis of the effect of socioeconomic status found that the most disadvantaged group of the population (Group 1), despite being 1.7% of the Western Australian population, accounted for 34% of cellulites cases. This indicates that they are 20 times more prone to cellulitis than their predicted level based on the rest of the population. Group 2 (7.7% of WA population) had 19% of cellulitis episodes, being three times higher than the highest SEIFA group. While Group 3 (38.8% of WA population) suffered 18% cellulitis and Group 4 (26.9% of population) had only 14% cellulitis
Figure 2: The rate (per million people) of cellulitis in each remoteness of access zone (ARIA) in Western Australia.

Figure 3: The rate (per million people) of cellulitis in Western Australia, across SEIFA (Socioeconomic Index of Disadvantage) quintiles, 1 being the most disadvantaged quintile through to 5, the most advantaged.
Finally, Group 5 (the most affluent group of WA society), which is a little over a quarter of the population, accounted for just 13.7% of all cellulitis cases. Adjusting for population size, the poorest quintile of the population was 7–10 times more likely to be hospitalised than the rest of the population (Figure 3).

Comparison to England

Comparing the rates (per million) of hospitalisation for cellulitis (during the decade in question) between England and Western Australia, in Western Australia the rates were significantly higher for all years of the study (Figure 4).

**Figure 4**: The rate (per million people) of cellulitis for each financial year 1999/2000 to 2008/2009 for the United Kingdom and Western Australia.

Note: UK data - Re-used with permission from the NHS Information Centre. All rights reserved.
Indigenous status

Aboriginal and Torres Strait Islander people were almost 7 times over-represented compared to non-Indigenous Western Australians (Figure 5).

![Figure 5](image)

Figure 5. The rate (per million people) of cellulitis for Aboriginal and Torres Strait Islander people and non-Indigenous people in Western Australia.

Discussion

The almost uniquely focused nature of the condition in the poorest 1.7% of the Western Australian population (more than 30 times effect) and the extreme multiplying effect on being a person of Aboriginal or Torres Strait Islander heritage (10+ times effect) gives a clear target grouping for addressing general dental health. It would be interesting to determine the level of service access opportunity for these two subsets of the population to dental services. Previous work from our group has shown that service distribution is tilted away from these groups, with clinical access (by cost and by distance from clinic) highest in the wealthiest most-
populated regions of the state. It is clear that a fuller dissection of service accessibility for teenagers and those in their early 20s are important issues that need further follow-up. The rate of cellulitis being highest in the younger adult is a most interesting finding. The clinical history to lead to a cellulitis is not always one that develops rapidly. Coupled with some of the world’s highest rates of third molar extraction\textsuperscript{10} is a universal coverage School Dental Service (SDS) model in Western Australia.\textsuperscript{11} This model covers all school-age children to the age of 15 (in some places 17) with free access to dental care. It is evident that after cessation of SDS access there is a coincident substantial rise in the rates of cellulitis, which peaks in the early 20s at some 7 or more times the rate in school-age children. In the late teenage years, with the development of personal health monitoring and self-determined access to care, there could well be a loss of focus on seeking dental care, which could lead to a slow deterioration of oral health that leads to this early peak in cellulitis rates. A question clearly raised from this work is the long-term life change effect of an SDS design. It could be argued that the service approach masks underlying health motivations but its removal sees ‘normal’ behaviours return, which raises questions for its long-term effectiveness on a population level. This dramatic hypothesis should lead policymakers to consider the effectiveness of such services, particularly in environments where near universal fluoride access is in place. The reduced level of decay in children is strongly linked to topical fluoride exposure (water and toothpaste) but little research shows the effectiveness of SDS\textsuperscript{12}. Therefore, policymakers would need to consider the sustainability of services with such universal coverage (and their operational costs) on the basis of how effective they are at changing long-term health behaviour and in relation to other population-level preventative measures.

It is also of interest that the rates of cellulitis in Western Australia are, year-on-year, higher than that of the UK. This international comparison (with a comparable
country) provides an interesting basis for further research examining the factors at play. Already, research from the UK has noted that the number of admissions as a result of odontogenic infections have increased most among poorer people in the UK, which is consistent with our findings although at an overall lower rate\textsuperscript{13}. This may point to a similar story, but of greater poverty, in Western Australia or other factors such as population distribution and service accessibility may be at play\textsuperscript{14}. Research from India has shown the influence of socioeconomic factors on deep-neck infections that are mostly of dental origin\textsuperscript{15}. It is clearly evident that cellulitis and poverty are linked and international trends support the findings in Western Australia. A clear exemplar in the data presented in thesis and in related publications, is the linkage between cellulitis and Australia’s Aboriginal people. The poverty experienced by this marginalised group is well documented and leads to an overall health situation that culminates in a life expectancy some 10–20 years shorter than the rest of the population\textsuperscript{16}. The findings of a rate of cellulitis among the poor at some 20 times the rest of the population highlight the misery of the story presented. The data highlight the need for focused addressing of poverty at population level (and, in this case, specifically the correlation between oral health and poverty). The linkage between disease burden and poverty is a near universal health, social and economic conundrum of the 21st Century. Efforts to diminish poverty (and its ensuing social divide) in all societies throughout time have and will continue to be vital to advancements in the health of the population.
References


Chapter 7: Mapping isolation of risk for sporadic conditions:

Oral cellulitis in Western Australia

Background: The aim of this study was to apply geographic information system (GIS) models to determine the predicted risk of oral cellulitis.

Methods: A risk isolation model using Western Australian real hospitalization data for oral cellulitis from 1999 to 2009 (10 years), and socio-economic indicators, age and Indigenous status as risk indicators was developed. The fully integrated database was then computer geo-coded to allow the visualization of the data at three levels (core of the capital city Perth, Greater Metropolitan Perth, and State of Western Australia). Correlation coefficient analysis between the number of cases (over 10 years) and the relative risk location indicator was carried out for the city of Perth and for the rest of the State of Western Australia.

Results: The GIS maps derived from application of the developed risk location indicator demonstrate that the risk categorization paralleled the number of cases over the decade. Correlation coefficient analysis demonstrated a strong correlation (R²=0.55) between the number of cases (over 10 years) and the risk location indicator in metropolitan Perth.

Conclusion: The developed geographic risk index using existing data to predict disease risk on a regional basis could be used as a valuable tool for geographic isolation of risk related to oral cellulitis.
Introduction

Cellulitis of the mouth and submandibular region (oral cellulitis) is a rare, potentially fatal soft tissue infection of dental origin, with its most severe presentation (Ludwig’s Angina) possibly leading to oedema, distortion, and obstruction of the airway\(^1\). Oral cellulitis can be used as an indicator of significant dental disease in a society\(^2\), as it often reflects the end of spectrum of oral disease that starts with dental caries and ends with spread of infection to tissues surrounding the oral cavity.

Globally, a strong correlation between dental infections and poverty has been reported\(^3,4\), with an Australian study showing hospitalisations for oral cellulitis being significantly more common in the lower socioeconomic groups of the society who could not afford private health insurance\(^2\). Furthermore, Aboriginal and Torres Strait Islander people were significantly more affected (7 times over represented) compared with non-Indigenous Australians\(^2\).

Sporadic medical conditions can be problematic for risk assessment, as they occur in small numbers, which poses a statistical challenge, and they tend to follow non-predictable patterns.

A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth’s surface. The science of GIS is developing at a global level, and has many applications regarding dental and epidemiological research. This discipline may act as a decision-making tool in
dental public health and it might contribute to the formulation of policies. Worldwide innovative ways are being developed to harness the data integration and spatial visualization power of GIS.

The use of various information technology services and software, to solve public health issues has an exponential increase and has been vital to the understanding and treatment of health problems in different geographic areas. GIS applications include both hardware and software systems. These applications may include cartographic data, photographic data, digital data, or data in spreadsheets. The latter can include population demographics such as age, income, and ethnicity, and can then be used to produce maps illustrating geographical disease distribution. It has been successfully used previously, to geographically isolate the risk areas for sporadic disease occurrence.

One of the steps towards management of oral cellulitis in poor communities and within Indigenous populations is to determine the location of the clusters at highest risk within the population.

In this study, the aim was to apply GIS models, (based on a risk location indicator developed from existing case data), to determine regions of Western Australia that are predicted to have a high number of oral cellulitis cases. This type of predictive model can assist in focusing primary health resources to areas of risk and thereby reduce the substantial costs, and risks, associated with treating this condition.
Method

Western Australia is Australia's largest State, with about 2.6 million inhabitants; about 75% of this population live in the capital, Perth.

The data used for the purposes of this study were collected from the Western Australian Hospital Morbidity Data System (HDMS) \(^7\) under appropriate ethical approval (Ethics Committee of The University of Western Australia, approval number RA/4/1/5502) and covers a 10-year period, beginning from July to June 2009 (financial years). It was generated from recording every episode of discharge for cases of cellulitis of the mouth and submandibular region as the principal oral condition (K12.2), as classified by the International Classification of Diseases–tenth Australian Modification (ICD-10AM) \(^8\). These data were collected from all public and private hospitals in the State of Western Australia. Other variables included in the data-set were: patient’s age, main place of residence at time of hospitalisation, and Indigenous status. An Indigenous person is a person of Aboriginal or Torres Strait Islander descent (the first peoples of Australia) who identifies as such.

In conjunction with the data collected from the HDMS, the data from the Australian Bureau of Statistics (ABS) 2006 Census were within the time range of our study and were incorporated into our analysis \(^9\). The rate calculations for Western Australian Hospitalisation were then calculated using population data obtained from the census. Age, Indigenous status and Socio-Economic Indexes for Areas (SEIFA) category were included as risk indicators. SEIFA, Australian national index system for economic disadvantage \(^10\) is a national quintile index based on
deciles of the total Australian population. In SEIFA, the lowest scoring 10% of areas are given a decile number of 1, the second-lowest 10% of areas are given a decile number of 2, up to the highest 10% of areas which are given a decile number of 10. The 10 deciles were combined into 5 groups: 1- most disadvantaged; 2- above average disadvantaged; 3-average disadvantaged; 4- below average disadvantaged; and, 5-least disadvantaged. As the cellulitis cases per 100,000 people were 38 times over represented in group 1 and about 5 times over represented in group 2, compared to the other 3 groups, only groups 1 and 2 were included in the risk assessment study. The Age variable was divided into six sub-sets: 0-4, 5-14, 15-19, 20-34, 35-49 and 50-69 years. The Indigenous status variable has two sub-sets: Indigenous and Non-Indigenous.

In Western Australia, there are 155 geographic areas, which do not overlap, known as statistical local areas (SLAs). A total of 24 distinct rates (cases per 100,000 people) of cellulitis were computed dependent on the mix of the variables sub-sets (Table 1). Statistical Package for the Social Sciences v21 (SPSS Inc; www.spss.com) was used to produce the required population-based rates. Population data across each of the 155 SLAs from the Australian Bureau of Statistics (ABS) 2011 Census were distributed by age, Indigenous status and SEIFA. Using Excel v2003 (Microsoft; Redmond, WA, USA), the hospitalisation rate for each population subset derived from the Western Australian morbidity data was applied to the appropriate population subset (age, health Indigenous status, SEIFA) within each SLA. The integrated database was then geo-coded using QGIS (version 2.14) to allow the visualization of the fully integrated data model. SLA geographic locations were obtained from 2006 ABS census. Both real cases of cellulitis occurring between 1999 and 2009 and high-risk area were mapped and demonstrated at three levels (core of the capital city Perth, Greater Metropolitan Perth and State of Western Australia).
Using SPSS, Pearson’s correlation coefficient was calculated to determine the levels of correlation between the number of cases (over 10 years) and the risk location indicator (RLI) for metropolitan Perth (36 SLA’s), as well as for the rest of the State.

**Table 1:** Annual Admission rates per 100,000 population for oral cellulitis by Indigenous status, age and disadvantage.

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Results

Over the 10 years of data available for this study there were 762 cases of oral cellulitis. On average this was approximately 76.2 cases per year in a population of approximately 1.96 million people (Census 2006).

The risk location indicator (RLI) developed, rested on three fundamental known risk factors (determined from previous studies\(^2\)): poverty, Indigenous status and age. The variables for each SLA were determined from the census data and a risk indicator calculated for each. The location indicator has no upper-boundary with higher numbers representing higher probability.

From the maps, it was evident that the RLI paralleled the number of cases over the decade (Figure 1). With the low level of cases it was not expected to be a precise match. This is particularly noticeable in the rural and remote regions of Western Australia where higher RLI levels were seen whilst case numbers were relatively low. Correlation coefficient analysis was applied to city and country data separately (Figure 2). The correlation between total cases over the decade in the city was strong (\(R^2=0.55\)) whereas (not unexpectedly) the correlation for the rest of the State was lower (\(R^2=0.27\)). Further analysis of the non-city based data, by dividing it into larger (greater than 10,000) and smaller SLAs did not change the lower level of correlation in the non-metropolitan areas (Figure 2).

Those results show that this risk location indicator (RLI) for a sporadic condition could be a reliable measure of risk for oral cellulitis in cities, but less effective in the lower, more widely dispersed population mix of rural and remote regions.
Figure 1: Top Left: Central Perth—Geographic distribution of the number of cases in the last 10 years (circles) and current risk indicator (colours) for oral cellulitis. (Cross hatched Statistical Local Areas are the city of Perth). Top Right: Metropolitan Perth: Geographic distribution of the number of cases in the last 10 years (circles) and current risk indicator (colours) for oral cellulitis. Bottom Left: State of Western Australia (Northern area) - Geographic distribution of the number of cases in the last 10 years (circles) and current risk indicator (colours) for oral cellulitis.
Figure 2: Correlation coefficient analysis between the number of cases (over 10 years – vertical axis) and the risk index (logarithmic scale – horizontal). For all of Western Australia (top left), Major capital city only (bottom left), rural areas with SLA population above 10,000 (top right) and rural areas with population below 10,000 (bottom right).

**Discussion**

This research used data from both the Australian Bureau of Statistics (ABS) census and the Australian Classification of Disease coding system (ICD10) to develop high resolution maps for oral cellulitis risk. In each map, it is clear that a higher number of (real) cases were found in areas where the risk model proposed would be a high risk of oral cellulitis. The correlation was higher at the city level (Figure 2) than in rural/regional areas. This could be explained by the low population level in rural areas.
The obtained maps, on multiple levels, could identify areas where oral health services might be needed, or delivered differently, across Western Australia. Oral cellulitis could be considered a measure of the extreme level of dental disease\(^2\), and its analysis could be used to study the overall dental service uptake.

Non-normally distributed oral cellulitis is an example of how traditional single parameters, such as average and incidence, could not be properly applied to the over-all population\(^1\). When examining the over-all incidence of this condition in Western Australia over the last 10 years, as previously reported \(^2\), the annual rates per million ranged between 25 and 60 cases, which was higher than UK rates for the same period\(^2\). However, at the level of sub-groups, the picture looks more alarming, with poverty and Indigenous status strongly affecting the number and rates of this condition\(^2\). The most disadvantaged group shows an annual rate of 771 cases per million (77.1 per 100,000), which is over 30 times the rate of some of the richer (less disadvantaged) groups\(^2\).

The major limitation of the study is the pooling of cases over 10-year period, which is due to the low number of cases of oral cellulitis. This is related to the rarity of this sporadic condition.

The majority of oral cellulitis cases arise from dental origin \(^{12\text{-}14}\), namely dental caries. There are many factors that could contribute to caries leading to oral cellulitis, however both water fluoridation, and availability of dental services in proximity to household play a major role. Most of the Australian population have access to water with regulated levels of fluoride \(^{15}\). However, only 12.5% of Indigenous communities in Western Australia have access to water with tested fluoride levels of greater than 0.5 ppm\(^{15}\), which may contribute to the higher levels of caries in these communities, and which may subsequently lead to higher rates of
oral cellulitis. Dental practice to population ratio is significantly higher in wealthy populated areas in Western Australia \(^{16-18}\), which makes it more difficult for people living in more disadvantaged (poorer) areas to access regular preventive dental care.

As the management of oral cellulitis in hospital settings should ideally be carried out by a specialist oral maxillofacial surgeon, it should be noted that currently there are only 23 oral surgeons (22 oral maxillofacial surgeons and 1 oral surgeon), in Western Australia\(^9\), providing service to its 2.6 million population \(^8\). This rate of 1 surgeon for every 113,600 population is below the overall Australian rate of 1 surgeon for every 94,600 population. What is more, Western Australia has one of the highest rates in the world for impacted wisdom teeth removals under General Anaesthesia \(^{20}\) by oral maxillofacial surgeons (7 times more than the UK), which is mainly elective for removal of asymptomatic impacted teeth \(^{21}\). This procedure was reported to represent 36% of their clinical activities\(^{22}\). This situation may question the availability of oral surgeons to respond effectively and in timely manner to oral cellulitis hospitalisations, leaving them to be managed by lesser trained emergency dentists. This may be more significant in rural Western Australia, where previously reports indicate lower accessibility to oral and maxillofacial services \(^{23}\).

**Conclusions**

In conclusion, the developed geographic risk index using existing data to predict disease risk on a regional basis could be used as a valuable tool for geographic isolation of risk related to oral cellulitis.
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Chapter 8: An approach to risk isolation for relatively low-incidence conditions: An Australian national model of oral cellulitis.

Abstract

Aim: The purpose of this study was to develop a risk indicator applicable on a national level, to isolate at relatively high-resolution, regions where oral cellulitis risk is high.

Method: The method used ten years of Western Australian (1999 to 2008) hospitalisation data, and applying the admission risks gleaned from this database (poverty, socioeconomics, age and Indigenous status) to model across Australia (at SA1 level) the risk profile. Five levels of oral cellulitis risk (low to very high) were mapped to each of the 54,000 SA1s that makeup Australia. Cumulative percentage analysis was used to study the effect of distance from capital city of each state on the number of population at high risk.

Results: Highest risk category (category 5) SA1s were not equally distributed amongst States, with the Northern Territory having 12.2% of its population (26011) belonging to category 5 (very high risk). The majority of that population (87.8%) live more than 100km away from the capital city, Darwin. A general trend amongst Australian capital cities was the low number of population at high risk within 5 km from General Post Office (GPO).
Introduction

The isolation of risk to specific geographic areas is an important tool for prevention and management of sporadic conditions, as those conditions usually occur in small numbers and tend to follow non-predictable patterns\(^1\). One common strategy for such risk isolation has been to statistically analyse multiple geographic variables\(^2\). However, it could be challenging to establish such a model in conditions where geographic variables (e.g. altitude, weather or distance from the sea) pose little or no effect. Another recently used method for risk isolation for sporadic conditions is to geocode variables to specific administrative units\(^1\) using Geographic Information Systems (GIS).

Oral cellulitis is a rare, sporadic and potentially fatal condition which is predominately a complication risk of untreated dental caries\(^3-^7\). In the Australian context, oral cellulitis is closely related to poverty, age and Indigenous status\(^7\). The majority of the Australian population live in the major cities (Melbourne, Sydney, Brisbane, Adelaide, Perth, Hobart, Canberra and Darwin)\(^8\), however, people who live in regional and rural areas have higher rates of dental caries\(^9\).

Oral cellulitis could be used as an indicator of the level of oral health in a society. The purpose of this study was to develop a risk indicator applicable on a national level, to isolate at relatively high resolution in Australia, regions where oral cellulitis risk is high. The distribution of the population at risk of oral cellulitis will be studied with the effect of distance from the centre of the capital city of each state.
Method

Baseline Risk Analysis

Ethics approval for this study was obtained from the Ethics Committee of The University of Western Australia, (approval number RA/4/1/5502). Data used were from the Western Australian Hospital Morbidity Data System (HMDS)\(^\text{10}\). It contained every episode of discharge from hospitals for cellulitis of the mouth and submandibular region as the principal oral condition (K12.2), as classified by the International Classification of Diseases–Tenth Australian Modification (ICD-10AM).\(^\text{11}\) The data included the age of patients, as well as the place of residence at time of hospitalisation and Indigenous status. The data obtained were for a period of 10 years, from July 1999 to June 2009. Population data obtained from the Australian Bureau of Statistics 2006 Census were used to calculate the rates for Western Australian Hospitalisations, as this was the near midpoint population data for the hospitalisation data.

The risk indicators used were age: Indigenous status and Socio-Economic Indexes for Areas (SEIFA) quintiles, as these variables are closely associated with oral cellulitis\(^\text{1}\). SEIFA is a coding system that categorizes all Australia into quintiles of socioeconomic status: most disadvantaged, above average disadvantaged, average disadvantaged, below average disadvantaged and least disadvantaged. The first two quintiles have been used in this study, as previous research has shown the first group to be 30 times more affected by oral cellulitis as opposed to more advantaged groups\(^\text{1}\). The three less disadvantaged quintiles (3, 4 and 5)
have been combined into one single group as they account for a significant number of cases, (but a low incidence per 100,000, as the majority of the Australian population belong to those three categories). Six sub-sets of age groups were used for this study: 0-4, 5-14, 15-19, 20-34, 35-49 and 50-69 years, based on previous study methodology\(^1\). Indigenous status (yes or no) was the final risk variable. A total of 36 distinct rates (cases per 100,000 people) of oral cellulitis were computed using Statistical Package for the Social Sciences v21 (SPSS Inc; www.spss.com) dependent on the mix of the variables sub-sets (SEIFA (n=3), Age (n=6) and Indigenous status (n=2)).

National modelling

The Australian Statistical Geography Standard (ASGS) divides Australia into SA1 regions as the smallest non-overlapping, non-gap statistical cover of Australia. This system commenced in 2011 as the basis of the census data. The modelling of relative risk computed in this study was completed using these geographic and population data (ABS 2011). SA1s generally have a population of 200 to 800 persons, and an average population of about 400 persons. Each SA1 has complete data on age groups, SEIFA groups and Indigenous status, as per the national census.

Using Excel v2003 (Microsoft; Redmond, WA, USA), the risk for each population subset derived from the Western Australian morbidity data was applied across Australia to the appropriate population subset (age, SEIFA and Indigenous status) within each SA1 as outlined by the Australian Bureau of Statistics.

A total of 17.4million Australians (about 80.1%) had a risk index under 0.1 and they were then excluded from the risk mapping (a total of 44695 SA1s) as having a
minimal or insignificant risk. The remaining 20% (approximately 4 million people) have been categorised into 5 equal sized (on population) categories: highest risk 20% of population (very high risk), second 20% at risk (high risk), third 20% (moderate risk), fourth 20% (low risk) and last 20% (very low risk).

The integrated database was then geo-coded using QGIS (version 2.14) to allow the visualisation of the fully integrated data model all over Australia. This methodology has been previously used for other conditions\textsuperscript{12}.

A comparison between population at risk was further made using Excel, according to each State and Territory. Using QGIS, SA1s corresponding to the highest risk categories (High risk and very High risk) (using centroids) within 100 km from the GPO (General Post office) of each capital centre of each Australian State/Territory (Sydney, Melbourne, Brisbane, Perth, Adelaide Canberra, Darwin and Hobart) were selected for further analysis. Those SA1 units were then further separated into bands according to their distance from the GPO. The selected bands were 0-2, 2-5, 5-10, 10-20, 20-40, 40-60, 60-80, 80-100 km distance from GPO. All SA1s (centroids) in the selected bands were exported into Excel for cumulative percentage analysis.

**Results**

The national Risk Locator Indicator (RLI) for oral cellulitis was mapped for Australia (Figure 1), with category 1 (very low risk) as light yellow, category 2 (low risk) as orange, category 3 (moderate risk) as dark orange, category 4 (high risk) as red and category 5 (very high risk) as dark red.
The number of the population at risk of oral cellulitis, by State and Territory, for the 5 categories of risk is shown in Table 1, and in Table 2 for the 100km buffer zones around the capital cities. The population belonging to the highest risk category (category 5) was not equally distributed amongst States and Territories, with the Northern Territory having 12.2 % of its population (26011) belonging to category 5 (very high risk). The majority of that population (87.8 %) live more than 100km away from the capital city, Darwin.

The cumulative percentage of population affected by oral cellulitis risk categories 4 and 5 (high risk and very high risk) for the selected bands of distance from GPO of capital cities (0-2, 2-5, 5-10, 10-20, 20-40, 40-60, 60-80, 80-100 km) is reported in Table 3 and Figure 2. A general trend amongst Australian capital cities was the low trend of risk within 5 km from GPO. This continues to be the case until 10 km for Brisbane, Melbourne and Sydney, with a similar gradual increase of percentage of population at risk after 10 km for those 3 cities. For Hobart, Adelaide and Perth, the percentage of population at risk increases gradually from the 5-km band. Darwin, however, has a specific plateau between 20 km and 60 km, followed by a very high-risk band between 60 and 80 km (accounting for 44 % of whole population at risk).
Figure 1. Relative risk index for Sydney (top left), Brisbane (top right), Adelaide (middle left), Melbourne (middle right), Perth (bottom left) and Australia (bottom right).
Table 1: Oral cellulitis risk in Australia by population (groups 1 to 5: very low risk, low risk, moderate risk, high risk and very high risk) by States and Territories: NSW: New South Wales, VIC: Victoria, QLD: Queensland, SA: South Australia, WA: Western Australia, (Northern Territory (Darwin), TAS: Tasmania, ACT: Australian Capital territory

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Table 2: Oral cellulitis risk within 100 km from capital cities by population (groups 1 to 5: very low risk, low risk, moderate risk, high risk and very high risk) by States and Territories: NSW: New South Wales (Sydney), VIC: Victoria (Melbourne), QLD: Queensland (Brisbane), SA: South Australia (Adelaide), WA: Western Australia (Perth), TAS: Tasmania (Hobart), NT: Northern Territory (Darwin), ACT: Australian Capital Territory (Canberra).

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Table 3: Cumulative percentage of population belonging to risk categories 4 and 5 (high risk and very high risk) according to distance for all States and Territories in Australia by distance from GPO.

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Discussion

This research has established a geographic risk indicator of oral cellulitis in Australia. The method relied upon analysing hospitalisation data for 10 years in Western Australia, identifying the strongest risk indicators (poverty categories SEIFA, age and Indigenous status based on admission trends) and applying these at a small area level across the total population of Australia. The resulting maps show, with the highest available granularity, the areas with high risk of oral cellulitis. This localisation of high risk areas could assist health authorities in identifying the
most appropriate locations of future dental centres, as well as School Dental Services (SDS) in those areas, to pre-emptively reduce cases of cellulitis though more robust primary health initiatives in these areas of risk.

This study found a very high proportion of the population at very high risk in rural and remote Northern Territory. This is not surprising as in the Northern Territory around 30% of population are Aboriginal and Torres Strait Islander people\(^8\). Furthermore, 43.2% of Australian Indigenous population live in outer regional, remote and very remote areas, as opposed to 10.4% of non-Indigenous population\(^8\).

Another finding was the low number of population at risk of oral cellulitis in proximity to the GPO of capital cities, especially for Sydney, Melbourne and Brisbane, where the risk was significantly very low within 10 km from the core of the city. This may be an indicator of people of relative high socioeconomic status living in the inner-city centres, as well as the growing trend for more senior aged people to take-up apartment living in these areas, which changes the relative population risk for conditions such as oral cellulitis.

The analysis used poverty, age and indigenous status to develop the risk locator indicator. Oral infections have been reported to be of higher incidence in the poorest population groups of the society in the UK\(^{13}\), the US\(^{14}\), India \(^{15}\) and Australia\(^7\). A 2014 US study\(^{16}\) on oral cellulitis and Ludwig’s Angina found higher rates of admission to hospital at non-white (40%) and found age and insurance status to be factors associated with hospital admissions. Those results may be comparable to the trends used in this research as in Australia, 3% of the population are Aboriginal and Torres Strait Islanders\(^8\), who are reported to suffer from low level of dental health\(^{17}\) and are generally more prone to be admitted to hospital\(^{18}\).
GIS has been previously used to study geographic access to dental services\textsuperscript{19} and to map the incidence of dental conditions\textsuperscript{12}. However, the application of computer-based GIS technique for risk location of sporadic dental condition used in this model could be useful for risk assessment of other dental and medical conditions. One interesting aspect of the current study was the pooling of the hospitalisation data for 10 years, which may be considered a relatively long period. However, this is not uncommon in similar conditions\textsuperscript{15} and could be further justified in this sporadic condition by the low annual incidence of cases.

The use of hospitalisation data from one State (Western Australia) as a representative sample for national model extrapolation could be considered a limitation of this study. Western Australia is the largest state in Australia by area with a diverse population of over 2.5 million people (being a 10-15\% of the national population). The extrapolation of Western Australian data nationwide has been previously used\textsuperscript{12,20} as the hospitalisation data (poverty, Indigenous status) are not openly accessible in Australia on a national level. Furthermore, estimating nationwide hospitalisation trends based on a representative sample is commonly used practice\textsuperscript{14,16, 21}.

In conclusion, this innovative method has provided a basis for examining the risk of cellulitis across a nation. Oral cellulitis was examined and specific areas of relative risk were identified. These types of approaches provide an evidence-based systematic approach to targeting primary care (and prevention) to specific communities to reduce the substantial burden to society that cases of high risk sporadic conditions incur.
References

1- Anjrini AA, Kruger E, Tennant M. Mapping isolation of risk for sporadic conditions: Oral cellulitis in Western Australia (submitted)


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Chapter 9: General Discussion

The purpose of this thesis was to study two dental conditions in Australia that lead to hospital admissions: removal of impacted wisdom teeth (third molars); and management of oral cellulitis. The research suggests that the former, a condition of the wealthy (80 percent privately insured), is mostly prophylactic and arguably unnecessary, while the latter, a potentially life-threatening condition, is associated with poverty and indigenous status, with the poorest sectors of the community 30 times more affected than the wealthy.

The research found that the rates of surgical removal of impacted wisdom teeth in Australia could be higher than comparable OCED countries (Countries signed the Convention of Organization for Economic Co-operation and Development).

Two countries which use similar ICD10 coding system were compared to Australia and after adjustment for population, Western Australian rates were 7 times higher than England (which has regulating, binding guidelines), and 50% higher than France (which does not have guidelines). This was the first application of the ICD10 coding system to compare dental related hospital internationally.

This application could provide the basis for similar research projects world-wide to compare other conditions internationally as many countries have open access to their ICD10 data.

The introduction of NICE guidelines in England has significantly reduced the number of hospital admissions for impacted third molars, as outlined in this thesis and also by Renton et al\textsuperscript{6}. However, the research contained in this thesis also
suggests that the introduction of NICE guidelines in England may have stopped the rates of hospital admission from increasing alarmingly, as they did in Australia and France.

The current results reveal that Australian rates were 7 times higher than England, and 50% higher than France could should be alarming for dentists, orthodontists, oral surgeons, the general Australian population as well as Australian health regulators.

The higher rates of third molar surgical removal in Australia could be attributed to an array of absences in regard to both binding guidelines and professional body (ADA) recommendations for the management of impacted third molars. The results could outline the need for new guidelines (binding or non-binding) to help health care providers and patients in taking the decision of monitoring asymptomatic impacted third molars. The results should outline the need for new guidelines (binding or non-binding) to help health care providers and patients in taking the decision of monitoring asymptomatic impacted third molars.

As the majority of these admissions (with high expenditure) are likely to be prophylactic, watchful monitoring was proposed as an alternative and a cost effectiveness analysis was carried out for this strategy. This analysis showed that watchful monitoring was a substantially more cost-effective alternative in the Australian context. A more focused surveillance for adjacent caries was also recommended by Renton et al. The proposed watchful monitoring strategy, including an OPG every two years and a thorough clinical examination for
periodontal pockets and caries would be an improved version of the NICE prescription.

Another potential driver behind patient acceptance for surgical removal of asymptomatic wisdom teeth could be the availability of insurance coverage. As a study held in the United States found that the main factor contributing to patient acceptance for the removal of wisdom teeth was the availability of insurance coverage¹. In Western Australia, 80% of patients who underwent the procedure were privately insured and the majority of these procedures were carried out in private hospitals².

Orthodontists and general dentists are the referring practitioners who diagnose the presence of asymptomatic third molars and advise the patient or his/her parents of the appropriate course of action. There is a tendency amongst orthodontists to recommend prophylactic removals of impacted third molars to prevent relapse, even though there is no sound evidence to support this view³. The US cohort study has shown that general dentists recommended removal of third molars for 59% of their patients, and that the vast majority of those cases were asymptomatic¹.

Orthodontists may have another motive, which is the fear of litigation in case of relapse, years after the end of treatment if they did not recommend third molar removal⁴.

It is noted that in 2016, the American Association of Oral Maxillofacial Surgeons (AAOMS) updated its White Paper for the management of third molar teeth⁵. The AAOMS’ current view states that in the absence of disease or significant risk of disease, active clinical and radiographic surveillance is indicated.
Media coverage and public opinion could be a key driver in the Australian context with regard to the formulation of new guidelines. In England, one of the steps towards the implantation of NICE guidelines was raising public awareness through media coverage in 1990s⁶.

The consequences of the introduction of guidelines in Australia comparable to those in the UK could be substantial. The research in this thesis estimates that this could incur an estimated 85% reduction in hospital surgical removal of impacted wisdom teeth. Binding guidelines by the regulating body (Dental Board of Australia) comparable to NICE guidelines could lead to a decrease of the number of hospital admissions. The ramifications of this would be widespread not only impacting hospitalisation bed vacancies but would also lead to a large drop in OMFS workloads. This decrease could be equivalent to an estimated 80 FTE (Full-Time Equivalent) practitioners. This is equal to one third of OMFS in Australia⁷, as third molars removals are reported to represent 34% of all surgeons’ practice time⁸. Furthermore, the application of UK rates to Australia may face some barriers such as different remuneration and referral systems, different care pathways, different levels of availability of care, as well as the effects of tradition and culture. In the UK, surgical removal of impacted teeth is generally covered by the NHS, with a contribution of £59.10 ($AUD 110) from the patient if provided in a dental clinic. If hospital treatment is required, it will be provided through the NHS free of charge. This reflects a significantly larger contribution from the Health system in UK than the Medicare in Australia. This may indicate how the introduction of guidelines similar to NICE in Australia could be more challenging to imply, as significant part of cost is paid by the patient and insurance companies, and also by the employers as loss of productivity.
Overall, further work needs to be carried out to establish the full impact of the proposed guidelines in Australia.

One of the limitations of this international comparison of hospital admissions to reflect the overall picture could be that it does not take in consideration impacted third molar removals occurring as outpatient or at the chair side, without hospital admission.

Another limitation in relation to the cost effectiveness analysis is to use estimates rather than precise number. Also, the use of a western Australian data as a representative sample for Australia-wide analysis would be less precise than the use of actual hospitalisation data from all Australian states.

The research contained in the second part of this thesis shows first evidence of association between oral cellulitis and both poverty and indigenous status in Australia. This could indicate that these two groups within the Australian population are experiencing much poorer oral health and persistent levels of oral disease than the larger majority.

It is also of interest that the rates of cellulitis in Western Australia are, year-on-year, higher than that of the UK. This international comparison (with a comparable country) provides an interesting basis for further research examining the factors at play. Already research from the UK has noted that the number of admissions as a result of odontogenic infections have increased most among poorer people in the UK, which is consistent with the current findings reported in this thesis, although at an overall lower rate. This may point to a similar story, but of greater poverty, in Western Australia or other factors such as population distribution and service
accessibility may be at play. Research from India has shown the influence of socioeconomic factors on deep-neck infections that are mostly of dental origin.

It is clearly evident that cellulitis and poverty are linked and international trends support the findings in Western Australia. A clear exemplar in the current data is the linkage between cellulitis and Australia’s Aboriginal people. The poverty experienced by this marginalised group is well documented and leads to an overall health situation that culminates in a life expectancy some 10–20 years shorter than the rest of the population.

The present findings of a rate of cellulitis among the poor at some 20 times the rest of the population continue the gravity of the story presented. The data highlight the need for focused addressing of poverty at population level (and, in the current case, specifically the correlation between oral health and poverty). The linkage between disease burden and poverty is a near universal health, social and economic conundrum of the 21st century. Efforts to diminish poverty (and its ensuing social divide) in all societies throughout time have and will continue to be vital to advancements in the health of the population.

To assist in focusing primary health resources to areas of risk and thereby reduce the substantial costs, and risks, associated with treating oral cellulitis, GIS models were applied to determine regions of Western Australia that are predicted to have a high number of the oral cellulitis cases. A risk indicator applicable on a national level to isolate at relatively high resolution in Australia, regions where oral cellulitis risk is high using GIS was established. The distribution of the population at risk of oral cellulitis was studied with the effect of distance from the centre of the capital city of each state. This localisation could be very helpful in planning the location of future dental centres as well as School Dental Services (SDS) in those areas, to
pre-emptively reduce cases of cellulitis though more robust primary health initiatives in these areas of risk.

The research contained in this thesis indicates that there is a large use of resources towards the arguably unnecessary prophylactic removal of third molars. Moreover, that is largely centred on the more affluent sectors of Australian society. In view of the findings related to the association of oral cellulitis with poverty and indigenous status, more resources should be dedicated to dealing with the prevention of this potentially fatal condition affecting the poorest sectors of society.
References


Chapter 10: Appendices
Appendix 1

Summary of appraisals and media coverage

Anjrini AA, Kruger E, Tennant M. International benchmarking of hospitalisations for impacted teeth: a 10 year retrospective study from the United Kingdom, France and Australia. British Dental Journal. 2014; 216: E16 1-4

- An article in the major daily newspaper in Western Australia. No wisdom in tooth removal, The West Australian, Page 3. January 22, 2014 by Nick Butterly, Canberra (Appendix 3). A response to this research findings from Dr Paul Sambrook, Head of Discipline Oral and Maxillofacial Surgery (OMS) Faculty of Health Sciences, The University of Adelaide was included, as well as comments from the Australian Dental Association.
- A tv interview with the research supervisor by TV channel 7 on 22/01/2014
- ABC Radio WA Morning News. Interview with research supervisor on 22/01/2014
- A nomination by the school of Anatomy, Physiology and Human Anatomy in the University of Western Australia for the 2014 Prize for Higher Degree by Research Achievements (appendix 4)
- A formal appreciation from the BDJ editors as one of the most read and downloaded articles of that issue. (appendix 5)


- ABC Science (Australian Broadcasting Corporation): Wisdom teeth: are we removing them more often than needed? Article by Anna Salleh, 17 August 2015 (Appendix 6). It contained a response to this research from Dr Rick Olive, president of the Australian Dental Association. http://www.abc.net.au/science/articles/2015/08/17/4283895.htm
- Commentary by Professor Laurie Walsh, Professor of Dental Science in the School of Dentistry at The University of Queensland. ICROHE Bulletin, Volume 5, Spring 2015 (Appendix 7)
- Opinion article by the Australian Dental Association, on their website (Appendix 8), in response to this research. Available from https://www.ada.org.au/News-Media/News-and-Release/Latest-News/Wisdom-teeth-To-remove-or-not-to-remove
Appendix 2

Summary of:
International benchmarking of hospitalisations for impacted teeth: a 10-year retrospective study from the United Kingdom, France and Australia

A. A. Anjirni,1 E. Kruger*1 and M. Tennant1

Background The United Kingdom and its national healthcare system represent a unique comparison for many other developed countries (such as Australia and France), as the practice of prophylactic removal of third molars in the United Kingdom has been discouraged for nearly two decades, with clear guidelines issued by the National Institute of Health and Care Excellence (NICE) in 2000 to limit third molar removal to only pathological situations. No such guidelines exist in Australia or France. The healthcare systems in England, France and Australia all use the International Classification of Disease (ICD) coding system for diagnostic categorising of all admissions to hospitals. Aim This study rested upon the opportunity of a universal coding system and semi-open access data to complete the first comparative study on an international scale of hospitalisations for removal of impacted teeth (between 99/00 and 08/09). Results Our international comparison revealed significant differences in rates of admission, with England having rates approximately five times less than France, and seven times less than Australia. Those results could be explained by the implementation of guidelines in the United Kingdom, and the absence of similar guidelines in France and Australia.

EDITOR’S SUMMARY

Someone once quipped that it was not the person who invented the wheel who was a genius but rather, it was the person who invented the other three. A witty observation but one which I think is very relevant to this research paper. In essence the underlying theme is that as well as discovery or innovation it is development and application which provide the route to human progress.

The starting point of this paper, from Australian authors, was the NICE guidelines issued in the year 2000 in relation to wisdom tooth removal in the UK. Developed by a committee (not always a recipe for success) of 24 experts in health economics, epidemiology, public health and surgery, the guidelines recommended that the practice of extraction of pathologically free impacted third molars should be discontinued. In the intervening years, this has dramatically reduced the number of hospital admissions in particular for this surgical procedure under general anaesthetic. Although the exact clinical value and benefits of the guidelines have come under recent review and discussion in this journal, as in other forums, the interest of the authors of this paper has been to compare the effect of the guidelines with the health systems in two other countries, Australia and France, where no such restrictions apply.

Of great value is the finding that there appears to be very significant differences in the rates of hospitalisation for impacted teeth across the world. In terms of one country learning from another (the analogy of adding those other three wheels) the results raise the potential that the presence of good-quality clinical guidelines for dental procedures, especially those requiring access to sophisticated health system facilities, may have a beneficial influence on the future organisation and costs of healthcare; an area of third-party and personal expenditure coming under sustained and increasing pressure worldwide.

In this context the presence and application of the NICE guidelines in the UK (also reflected by the Scottish Intercollegiate Guidelines Network) provide a very useful case study which may have resonances further afield. Similarly, there may be opportunities for UK-based researchers to study guidelines in other countries in other areas of oral healthcare which might have significant benefits to us here in these islands.

The full paper can be accessed from the BDJ website (www.bdj.co.uk), under ‘Research’ in the table of contents for Volume 216 Issue 7.

Stephen Hancocks

DOI: 10.1038/sj.bdj.2014.264
RESEARCH QUESTIONS RATES

No wisdom in tooth removal

EXCLUSIVE

The West Australian

Wednesday, January 22, 2014

RESEARCH QUESTIONS RATES

No wisdom in tooth removal

EXCLUSIVE

NICK BUTLER

Canberra

Perth dentists are pulling wisdom teeth at unprecedented rates, a study claims, despite international research warning the procedure can do more harm than good.

A paper to be published in the British Dental Journal says WA has one of the highest known rates of impacted tooth removal in the world.

The study questions whether Australia needs strong guidelines for dentists making clear when wisdom teeth should be pulled.

Researchers at the University of Western Australia compared hospital admission rates between WA, the UK and France for em- bedded and impacted teeth over a 10-year period between 1999 and 2009.

The paper found the rate of hospital admission for impacted teeth in WA was nearly 75% per cent higher than England and 42 per cent higher than France.

Research in Britain in the 1990s suggested the removal of wisdom teeth had little effect on crowding of the teeth, one of the reasons dentists give for their removal.

The study led to new British advice being drawn up recom- mending third molars be pulled in extreme cases only and healthy teeth be left alone.

"Maybe it is time Australia looks to other places for stronger practice guidelines and to reflect on practice in WA, the differences are substantial and certainly need examining closely," one of the paper's authors, Profes- sorMarc Tennant, told The West Aus tra lian. "Interestingly, wis dom teeth extraction is predominated by teenagers from the city and those with insurance."

The paper's authors say their findings will be of interest to healthcare authorities and insur ance companies.

But oral and facial surgeon Paul Sambrook rejected any sugges tion Australian dentists were removing teeth without good reason.

"We have several deaths per annum from people who have teeth left in that should have been removed," he said.

Dr Sambrook, who also sits as the chair of the board of studies for the Royal Australasian Col- lege of Dental Surgeons, said it would be "fraught" to compare figures from Britain's National Health Service with Australian data.

A spokeswoman for the Aus tra lian Dental Association confirmed there were no Australian guidelines as there were in the UK on wisdom tooth removal.

Stuart Cairns, chief executive of the WA branch of the ADA, said he was unaware of any evidence of high rates of wisdom tooth removal in the State.
Appendix 4

7 May 2014

Dr Michael Azariadis
Graduate Education Officer
Graduate Research and Scholarships Office
M358

Dear Dr Azariades,

RE: Abed A. Anjrini– 2014 Prizes for Higher Degree by Research Achievements

Abed is currently a PhD student in the School of Anatomy, Physiology and Human Biology. In the last 12 months he has published a two papers in peer reviewed scholarly journals on the topic of his PhD research work, which relates to international comparisons of public health initiatives in 3rd molar (wisdom) tooth extraction. The paper that he is submitting for the Prize relates to the first ever reflection on trans-jurisdictional effects of evidence-based guidelines in oral health care:


The article raised substantial amount of interest, garnering both State and national media coverage (details are attached) as well as substantial professional interest. The outcomes of the work point government towards policy initiatives that could save Australia billions of dollars through the application of evidence based guidelines. Clearly, local controversy within the profession has been part of the process of publication.

The article, published in one of the world’s most widely read dental journals (The British Dental Journal) also was clearly a substantial piece in the United Kingdom. The editor of the journal made it his focus for an editorial (attached) and made it the Continuing Professional Development article of the month.

The British Dental Journal is one of the oldest and most respected dental journals in the world. It uses an independent and rigorous peer review system, which is conducted by qualified experts in the field. This Journal is listed on the Australian Research Council’s (ARC) Excellence in Research in Australia (ERA) 2012 Journal list, and is also listed in Thomson Reuter Web of Knowledge Master Journal list.

Dr Anjrini’s work at the international level has had substantial impact. At the national and local levels it has generated much consideration. It clearly points to opportunities for Australia to make substantial health savings over the next decades through the use of internationally recognized guidelines and points health executives and policy makers towards solutions for making a substantial impact on Australian society. I therefore strongly recommend Dr Anjrini for this award.

Sincerely,

Prof Shane Maloney
Appendix 5

From: Pacey, Laura [mailto:L.Pacey@nature.com]
Sent: Thursday, May 15, 2014 10:04 PM
To: Estie Kruger
Subject: Your recent BDJ paper

Dear Dr Kruger,

I hope this finds you well. I am writing to congratulate you as your BDJ paper *International benchmarking of hospitalisations for impacted teeth: a 10-year retrospective study from the United Kingdom, France and Australia*, was one of the top ten most viewed 2014 BDJ articles in April.

We invite you to send your highly accessed paper to your peers and colleagues, available [here](http://www.nature.com/nams/svc/myaccount/save/alert?list_id=29).

If you have not done so already, you can sign up for our e-alerts at [http://www.nature.com/nams/svc/myaccount/save/alert?list_id=29](http://www.nature.com/nams/svc/myaccount/save/alert?list_id=29).

Thank you for choosing to publish with us and we hope that you will consider the BDJ for your next paper.

Congratulations again and warmest wishes,

Laura

Laura Pacey
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Wisdom teeth: are we removing them more often than needed?

Anna Salleh Monday, 17 August 2015

Taking out wisdom teeth when you don't need to costs Australians millions of dollars say experts.

They say the evidence suggests it's best to leave them in unless they are causing problems.

But others argue such calls are driven by economic considerations rather than what's best for the patient. Researchers writing recently in the British Dental Journal argue dentists shouldn't remove impacted wisdom teeth that are not giving any symptoms. They say this approach, taken in the UK, is based on the best available evidence and saves money by leaving alone wisdom teeth that were never going to cause a problem in the first place. “The core message is using evidence to drive healthcare reform,” says Professor Marc Tennant of the University of Western Australia, who worked for 20 years in public health dentistry.

"In Britain when they started to apply some evidence-based criteria, the number of teeth they needed to remove dropped, and has remained relatively low over the past 10 years or so."

Wisdom teeth are the last of our teeth to emerge -- starting to appear by age 17. In a large proportion of cases the teeth become impacted, remaining hidden under the gums or pushing into other teeth. Dentists often remove impacted wisdom teeth to avoid the risk of problems such as pain, gum inflammation and decay.

But Tennant points to guidelines from the UK National Institute for Health and Care Excellence (NICE) that say only patients who have diseased wisdom teeth or other problems should have their wisdom teeth removed. The UK guidelines say there is no evidence that taking out asymptomatic teeth as a precaution benefits patients. Instead, they advise dentists keep a close eye on the teeth to see if they develop problems. Indeed, the NICE guidelines point out, surgery itself can lead to complications such as nerve damage, damage to other teeth, infection, swelling, bleeding, pain or affect a patient’s ability to open their mouth fully.

Rates of removal

Tennant and colleagues, including graduate student Abed Anjrini, previously found 527 per 100,000 Australians were admitted to hospital for impacted wisdom teeth removal in 2008/09 -- a rate seven times higher than in the UK and continuing to increase. In the new paper, the team calculate the savings that would result if Australia took a similar approach to the UK.

However, they included an even more stringent monitoring regime than that recommended by the NICE guidelines, including dental x-rays every two years. The researchers say a 'watchful monitoring strategy' would save Australians between $420-513 million a year, including indirect costs (for example time off work). Most of the costs involved in wisdom tooth removal in Australia are borne by individuals, usually drawing on their private health insurance.

Economic driver

But Dr Rick Olive, president of the Australian Dental Association, argues the approach taken by the UK, and recommended by Tennant and colleagues, is just a cost-saving exercise.

"This is the argument that is used by those who seek to ration healthcare," says Olive, who is currently involved in researching the impact of wisdom tooth removal himself.

He says there is not enough research to back evidence-based guidelines for impacted wisdom teeth removal, so it should be up to patients, advised by their dentists, to decide whether they want to take the risk of keeping their impacted wisdom teeth. An important thing to consider, says Olive, is that the older you are when you have your wisdom teeth out the more likely you will suffer complications from the surgery, which affects 5 to 21 per cent of people.

Watchful monitoring also means you will also receive extra radiation from dental x-rays in the meantime, he says.

Olive believes the UK approach just defers problems arising from wisdom teeth and will result in an increasing rate of surgical complications.

Although, he adds, we won’t know if this is the case for another 15 years.
Commentary on BDJ publication: Wisdom teeth
Professor Laurie Walsh

In the last couple of years one of the IRCOHE fellows Dr Abed Anjrini has published some outstanding works on wisdom tooth extraction in Australia. Most recently in the British Dental Journal (July) was an outstanding work looking at the costs of it to the Australian community. Professor Walsh has written a commentary on this article that we thought may stimulate some interest.

Over the past two decades, there has been much debate regarding the value of prophylactic removal of third molars, a practice which like routine tonsillectomy in teenagers has quite correctly been scrutinized more rigorously in recent times. A number of contemporary clinical guidelines have advocated a much more cautious approach to the management of third molars, namely watchful monitoring, which recognises the need to remain alert for the possible development of pathology later in the patient’s life. In the age of evidence based practice, it is timely to consider the costs to the broad health system of the various approaches. The paper by Anjrini et al. projects from actual data on third molar extractions in hospital settings in Western Australia the number for all of Australia and the anticipated costs over the 20 year period from age 15 to age 34, which represents the time when teenagers would be completing orthodontic care and where recommendations for prophylactic third molar removal may arise.

Following a watchful monitoring strategy for third molars was calculated to lead to savings in the order of $500 million AUD. Recognising that the study did not include the savings from third molar surgery performed in nonhospital settings such as in public sector or private general dental practices, one can regard these fiscal estimates as conservative. For individuals, the benefits of more conservative approaches to third molar management are considerable, since in Australia around 80% of the costs of dental care are met from personal income rather than from national government sources, and private health insurance typically covers only half the costs of extractions undertaken in office-based practice. Moreover, one must consider the non-fiscal benefits to individuals of following such a conservative strategy, in terms of reduced pain and suffering, from surgery which in many cases may not be necessary. A final consideration is that in the modern era with ready access to digital radiology and particular to cone beam volumetric tomography, we in the profession are better placed than ever before to more thoroughly assess the situation of third molar teeth, and thus better anticipate complications and plan for “as much intervention as needed, but as little as possible”. This has certainly been the case with ectopic or impacted canine teeth in orthodontics. It is timely to apply the same logic to third molars, and minimize invasive interventions.
Wisdom teeth: To remove or not to remove?

18 August 2015

There are two schools of thought when it comes to the removal of wisdom teeth.

One argues that wisdom teeth, which begin appearing around the age of 17, should be left in place unless they begin causing problems for the patient.

Others, however, contend that leaving them where they are is driven more by economic imperatives and less by the welfare of the person in question.

This second line of argument was recently written up in the British Dental Journal where researchers argued that leaving wisdom teeth alone saves money and is a key driver in the quest for healthcare reform.

UK practice shows that asymmetric wisdom teeth, which are teeth that haven't become impacted and caused problems such as gum inflammation and decay, don't cause any problems and should simply be monitored by dentists in case problems develop.

In Australia, the number of people admitted to hospital for the removal of impacted wisdom teeth is seven times greater than the UK version.

Researchers say that adopting the UK model would result in savings to the Australian healthcare system of $420-513 million.

However, the president of the Australian Dental Association Rick Olive is concerned that this argument is driven by people seeking to rationalise health care, and suggests that patients should be the one to make the decision in consultation with their dentists.
Appendix 9 (Published Article)
International benchmarking of hospitalisations for impacted teeth: a 10-year retrospective study from the United Kingdom, France and Australia

A. A. Anjini, E. Kruger* and M. Tennant

VERIFIABLE CPD PAPER

BACKGROUND The United Kingdom and its national healthcare system represent a unique comparison for many other developed countries (such as Australia and France), as the practice of prophylactic removal of third molars in the United Kingdom has been discouraged for nearly two decades, with clear guidelines issued by the National Institute of Health and Care Excellence (NICE) in 2000 to limit third molar removal to only pathological situations. No such guidelines exist in Australia or France. The healthcare systems in England, France and Australia all use the International Classification of Disease (ICD) coding system for diagnostic categorising of all admissions to hospitals. Aim This study rested upon the opportunity of a universal coding system and semi-open access data to complete the first comparative study on an international scale of hospitalisations for removal of impacted teeth between 99/00 and 08/09. Results Our international comparison revealed significant differences in rates of admission, with England having rates approximately five times less than France, and seven times less than Australia. Those results could be explained by the implementation of guidelines in the United Kingdom, and the absence of similar guidelines in France and Australia.

INTRODUCTION Approximately one fifth of humankind is affected by tooth impaction in some form,¹ and in most cases it is caused by the upper and/or lower third molars.² Slightly more than one fifth of impacted teeth in most developed countries is performed by a trained oral maxillofacial surgeon or oral surgeon (OMFS), and is commonly carried out under general anaesthesia. In a hospital environment (generally involving one day’s hospitalisation) with post-operative complications in up to 15% of the cases.³ Those complications can include sensory nerve damage (paraesthesia), alveolar osteitis (dry socket), infection, haematoma and pain. Rarer complications include severe trismus, oro-aural fistula, iatrogenic mandibular fracture and complications of general anaesthesia. It has long been established that impacted teeth need to be removed when they show any sign of associated pathology and/or severe symptoms.⁴ However, in a considerable percentage of the extraction cases (from 18 to 60%),⁵-⁷ prophylactic extraction of pathology-free impacted teeth has been reported. The reasoning behind this controversial prophylactic procedure is the prevention of pathological changes, decrease in future surgical complications and improvement in post-orthodontic treatment retention (decrease of late incisor crowding). The justification for this prophylactic surgery is disputed and has been debated for many years. In a recent update, and after extensive review of the literature, the Cochrane Database Systemic Reviews⁸ concluded that there is not enough evidence supporting the removal of asymptomatic impacted third molars. Furthermore, the authors described watchful monitoring of these asymptomatic impacted teeth as a more prudent strategy. The possibility of substantially decreasing the number of hospitalisations for impacted tooth extraction led to the introduction of the NICE Guidelines in 2000 in the UK.⁹ They were based mainly on the review of Song et al.¹⁰ and have been developed by a committee of 24 experts in health economics, epidemiology, public health and surgery. They recommended that the practice of extraction of pathology-free impacted third molars should be discontinued. Similar guidelines have also been established in 1999 by the Scottish Intercollegiate Guidelines Network (SIGN).¹¹ These unique guidelines have been followed by all dentists in the UK for the last 13 years. This study analysed data from a ten-year period (1999-2009) by examining hospitalisations for impacted teeth removals, and to compare the healthcare systems of France and Australia with that of the United Kingdom. The hypothesis being that in the UK the rates of hospitalisation for impacted teeth are significantly less than that of the other jurisdictions.

METHOD Hospitalisation data was collected for the three countries from open access sources for the United Kingdom and France. Data for Western Australia (one state of Australia) was obtained with ethics approval from the Research Ethics Committee of The University of Western Australia, as the data was closed access. In all three jurisdictions data for all those patients with the principal diagnosis of "KO: Embeded and Impacted teeth", as classified by the International Classification of Disease (ICD-10AM) system,¹² was included in this study.

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Western Australia

Data for analysis was obtained from the Western Australian Hospital Morbidity Data System (WHMDS), for ten financial years, from 1999/2000 to 2008/2009, discharged from any private and public hospital in Western Australia. This state represents just over 10% of the total Australian population and covers nearly 50% of the geographic area of Australia. Population estimates for each year were derived from the Australian Bureau of Statistics.

United Kingdom

Comparable freely available data for the decade was collected from the hospital episode statistics website (www.b NHSonline. nhs.uk) for the period from 1999-2000 to 2008-2009. All NHS trusts in England were included. The data also included private patients treated in NHS hospitals, patients resident outside of England but receiving care delivered by treatment centres (including those in the independent sector) funded by the NHS. No reliable data source was available for patients treated fully by the independent sector. As only 10% of population is covered by private insurance in the UK, their exclusion would not have had a significant effect on our comparative study. England’s population estimates for each year were obtained from the Office for National Statistics, UK.

France

Comparable freely available data for the decade was collected from the hospital episode statistics website www.aih.sante.fr, derived from the National Information System on Hospitalisation (SNATH) for the period from 1999 to 2008. All private and public hospitals in mainland France were included. French population estimates for each year were obtained from the French National Institute for Statistics and Economic Studies (INSEE).

Recording periods

It is noted that there is a slight difference in recording periods as a financial year in the UK is from 1 April to 31 March, in France from 1 January to 31 December, while in Australia a financial year is from 1 July to 30 June; however it is not expected that this margin effect (over a decade of data) will have any effect on the data. If it does, the level of effect would be at best tiny, relative to the results of the study.

To establish a quantitative comparison between the differently sized populations, hospitalisation rates per 100,000 population/year were calculated (total population approximately 50 million), France
(approximately 62 million) and Western Australia (approximately 2 million). These rates were not age standardized. All data was collated and analysed with Microsoft Excel (version 2003 Microsoft Corporation Redmond USA).

RESULTS

Overall numbers

There were a total of 88,286 patients hospitalised in Western Australia for removal of impacted/embedded teeth during the ten-year period 1999-2000 to 2008-2009. The number of patients admitted to hospital for this condition per year increased by 81% over the study period (Fig 1, Table 1), with an annual increase of between 1.2% and 23% per annum. In France, 1,834,613 patients were hospitalised for the same condition over the same period and the annual number increased by 36% over the decade. Most of the increase (32%) occurred between 1999 and 2005. In England 352,287 patients were hospitalised for impacted/embedded teeth. The number of patients admitted per year decreased by 20% over the study period. There was a sharp decrease of 61% between 1999/2000 and 2002/2004 followed by slow increase of 33% between 2003/2004 and 2008/2009 (Fig 1, Table 1).

Rates of hospitalisation

A comparison of rates of hospital admissions for impacted teeth per 100,000 population in England, France and Western Australia is depicted in Figure 2. The rate changes over the period followed the same trends as the total number of admissions (Fig 1). In 2004/2005 the rate for England was 61, France was 316 and Western Australia 455. This indicates that rates of admissions in Western Australia were significantly higher (740%) than England and 429% higher than France. While on the other hand, in France the rates were significantly (520%) higher than England. Toward the end of the study period (2008/2009), this difference remains substantial with Western Australian rates 690% higher than England and 60% higher than France. Similarly, rates in France were 430% higher than England.

DISCUSSION

Removal of impacted teeth under general anaesthesia offers the possibility of extracting multiple teeth at one admission, less discomfort to the patient, and thus the intention of providing a more cost-effective and efficient service, and also allows more viability to the oral surgeon.

Hospital admission rate recording for this purpose also offers the opportunity to closely monitor the trends of this practice over time, in a given healthcare system and on a large scale. This is particularly important when considering that a considerable percentage of the overall impacted teeth removals are performed as an in-office procedure, which is difficult to monitor in a statistically reliable way. The healthcare systems in the UK, France and Australia all use the International Classification of Diseases (ICD) coding system for diagnostic categorizing of all admissions to hospitals. As the same coding system is used for hospitalizations for removal of impacted/embedded teeth in these three countries, it was possible to draw the first comparative study on an international scale regarding hospitalisations for removal of impacted teeth (mainly third molars).

Our international comparison revealed significant differences in rates of admission for impacted teeth, which could be explained by the implementation of NICE guidelines in the United Kingdom and the absence of similar guidelines in France and Australia. As these countries are very comparable in terms of most factors affecting third molar pathology and the way dental services are delivered, other contributing factors such as insurance policies, cost of treatment and the number of oral maxillofacial surgeons and stomatologists – in the case of France – could not alone explain such substantial differences. Furthermore, those contributing factors could be closely related, as in the case of insurance policies and cost, to the presence/absence of the guidelines.

Interestingly, despite the fact that the vast majority of the research done on the role of third molars on anterior crowding revealed no significant effect, many OMG surgeons and orthodontists still believe that the erupting third molars are capable of pushing the anterior teeth forward, causing anterior crowding. As removal of third molars has been performed in order to prevent abnormal orthodontic conditions. It is likely that this purpose would be responsible for a considerable percentage of the cases in France and Australia.

Western Australia is the largest state of Australia with a population of around 2 million, which is a reasonably representative sample of the Australian healthcare system. We have previously examined the practice of hospitalization for removal of impacted teeth in Western Australia and shown the high related expenditure and the significance of associated factors such as indigenous status, age, gender and private hospital access along with insurance status. This study has clearly shown that the rates of hospitalisations for impacted teeth removal in Western Australia are substantially higher than the rates in UK and higher (but to a lesser extent) than the rates in France. These findings should be of interest to both healthcare authorities, and insurance companies, as it does present a significant economic impact, and also the possibility of some unnecessary hospitalisations, thereby further burdening the health system.

The impact of guidelines on the practice of third molar extraction in the UK has been reviewed by Renton et al. and by MacAnule and Renton. Between 1988 and 1994 the number of episodes in the UK was on the rise and increased by 3.7%. An overall decrease of numbers of third-molar-related hospital admissions was observed since the RCS guidelines were introduced in 1997, with a late slow increase since 2005, which has been attributed to rebound effect mostly caused by dental caries at an older age.

Those findings were found to be consistent with our analysis of the trends in England between 1999 and 2008.

The first reports on the third molar removal controversy in UK were published by Brickley and Shepherd and others.
between 1993 and 1996. Their work, as well as the extensive media coverage on this issue in the UK,\(^4\) has led to the development of RCS\(^3\) guidelines in 1997 followed by SNCS\(^4\) guidelines in 1999.

The first review of Song et al.\(^5\) (1997) and the subsequent commentary by Shepard\(^6\) (1998), together with the final report of Song et al.\(^5\) (2000) have been the basis upon which the National Institute of Health and Clinical Excellence (NICE) issued their guidelines regarding third molar management in 2000.\(^7\) They recommended that the practice of extraction of pathology-free impacted third molar should be discontinued and to limit this practice to patients with evidence of pathology. However, they only recommended a standard routine programme of dental care for pathology-free impacted third molar. This was recently criticised by Mansoor et al.,\(^8\) citing the need for periodontal panoramic radiography examination of impacted teeth, even in the absence of symptoms and signs. Furthermore, in view of their reported increase of caries to adjacent teeth, a more focused surveillance of mandibular third molars has been suggested by Renton et al.\(^9\) Those recommendations are consistent with the strategy of watchful monitoring of pathology-free impacted teeth, prescribed by the Cochrane Database Systematic Reviews.\(^10\)

**CONCLUSION**

The key finding from the present study was that there appears to be very significant differences in the rates of hospitalisation for impacted teeth across the world and raises the potential that the presence of good-quality clinical guidelines for dental procedures, especially those requiring access to high cost health system facilities and treatment, has the potential long-term opportunity to more efficiently, and cost-effectively manage care and target it to those most in need.

27. Brickley M, Shepherd J, Renton T. Third molars: represent a significant cost to patients with evidence of pathology. However, they only recommended a standard routine programme of dental care for pathology-free impacted third molar. This was recently criticised by Mansoor et al.,\(^8\) citing the need for periodontal panoramic radiography examination of impacted teeth, even in the absence of symptoms and signs. Furthermore, in view of their reported increase of caries to adjacent teeth, a more focused surveillance of mandibular third molars has been suggested by Renton et al.\(^9\) Those recommendations are consistent with the strategy of watchful monitoring of pathology-free impacted teeth, prescribed by the Cochrane Database Systematic Reviews.\(^10\)
Appendix 10 (Published Article)
Cost effectiveness modelling of a 'watchful monitoring strategy' for impacted third molars vs prophylactic removal under GA: an Australian perspective

A. A. Anjini, E. Kruger and M. Tennant

Objective To develop a national level cost model of both the direct and indirect costs of hospitalisations for impacted teeth in Australia. This model will then be used to compare a watchful monitoring strategy for impacted third molars versus prophylactic removal under GA, and calculate possible cost savings in the scenario where Australia would adopt guidelines comparable to the UK. Methods Western Australian real hospitalisation data for impacted/embedded teeth removal for 2008/2009 were extrapolated into a national, Australian-wide cost-distribution model for removal strategy. The components of a watchful monitoring strategy were calculated over a one-year and 20-year period. Cost estimates for both strategies were then compared. Results The estimated number of hospitalisations for impacted teeth in Australia in 2008/2009 for the age group 15–34 years was 97,949. The estimated average annual direct cost was $505 million, the indirect cost was $181 million and total cost was $531 million. Individual cost of the watchful monitoring strategy over 20 years was $1,077, with an annual estimated cost of $53. The proposed guidelines would lead to an annual figure of 83,850 individuals avoiding hospitalisation and shifting to watchful monitoring strategy, and an annual reduction of costs ranging between $420–$513 million. Conclusion With no evidence to support the prophylactic removal of asymptomatic wisdom teeth, a proposed watchful monitoring strategy is a more cost-effective alternative in the Australian context.

INTRODUCTION

The prevalence of third molar impaction in the general population is high, and has been reported to range between 18–60%. A global debate over the management strategy for impacted, symptomless third molars is continuing. One approach is to prophylactically remove them to prevent crowding of lower incisors, as well as to prevent possible pathologies such as caries of adjacent teeth, periodontal disease, cyst formation and infection, abscess or retrolatide. While this approach is supported by the American Association of Oral and Maxillofacial Surgeons, the prophylactic removal of impacted third molars was not supported by the American Public Health Association since 2008. Similarly in Europe, this approach was not supported by several reports such as Belgian Healthcare Knowledge Centre report (2012), Scottish National Clinical Guideline report (1998), Swedish health technology assessment (2000), Royal College of Surgeons of England report (1997) and National Institute for Clinical Excellence (NICE) guidelines (2008). At the other end of the spectrum of the debate is the strategy to closely monitor those impacted teeth over the rest of the life of the patient (watchful monitoring). The argument behind this approach is mainly to prevent complications of extractions, such as pain, bleeding, swelling, dry socket, trismus, damage to the nerve and to the temporomandibular joint, with the rate of complications reported to be between 4.6% and 21%6. In comparing these two models, the cost effectiveness of each strategy is an important factor in the design of healthcare policies and therapeutic guidelines.

In Australia, impacted teeth (mostly third molars) are usually removed under general anaesthesia by an oral maxillofacial surgeon. This procedure has been shown to be associated with masked individuals and at a relatively young age. Furthermore, it has been recently reported that the rates of hospitalisations for impacted teeth were one of the highest in the world, with Western Australia having rates of hospitalisation almost seven times (6.9%) that of England, where third molar removals are restricted to symptomatic cases, since 2000. Those findings suggest that about 85% of third molar removals in Australia are likely to be prophylactic.

The hypothesis of this study was that, in the Australian context, the direct and indirect costs associated with third molar removal in hospital would be substantially higher than the costs associated with the proposed watchful monitoring strategy. The aim was to estimate the number and characteristics of hospitalised patients for removal of impacted teeth, and use this to develop a national level cost model of both the direct and indirect costs of hospitalisations in Australia. This model will then be used to compare both strategies, and calculate possible cost savings in the scenario where Australia would adopt guidelines comparable to the UK.

METHOD

Baseline data

The base data was obtained from the Western Australian Hospital Morbidity Data System.
under appropriate ethical data release. Ethics approval for this study was obtained from the Human Ethics Committee of the University of Western Australia.

Every episode of discharge from all private and public hospitals in Western Australia for the financial year 2008/2009 for removal of impacted or embedded teeth as the principal oral condition, as classified by the International Classification of Diseases, Tenth Revision, Australian Modification (ICD-10-AM), was included in the dataset. The analysis also included patient age, insurance status and primary place of residence at the time of hospitalisation. All dollars presented in this study are Australian dollars, and at a fixed cost of living as at 2009, unless otherwise stated.

National model based on WA

Rates calculation

The rate calculations for Western Australian hospitalisation were then measured using population data obtained from the Australian Bureau of Statistics 2006 Census. Age, insurance status and socioeconomic indexes for areas (SEIFA) category were included as risk indicators. These driving variables have previously been shown to be strongly linked to third molar extraction rates in Australia. It is noted that the 2006 census data was chosen as to be closest to the 2008/2009 hospitalisation base data. The age variable was divided into four sub-sets: 15-19, 20-24, 25-29 and 30-34 years. As those age groups comprise 80% of all cases reported, ages <14 years and >35 years were not included as the small numbers would skew the modelling. The insurance status variable has two subsets: insured and non-insured. SEIFA is the nationally accepted coding for socioeconomic advantage and disadvantage in Australia. The five categories (subsets) for SEIFA are: most disadvantaged, above average disadvantaged, average disadvantaged, below average disadvantaged and least disadvantaged. A total of 40 distinct rates of third molar extraction were computed dependent on the mix of the variables subsets. SFSS version 21 was used to produce the required population-based rates.

Distribution of model nationally

Australia is divided by the Australian Bureau of Statistics into 1,353 non-overlapping/overlapping statistical local area (SLAs). The population data across each of the 1,353 SLAs were distributed by age, health insurance status and SEIFA. Using Microsoft Excel (2003), the hospitalisation rate for each population subset derived from the Western Australian morbidity data was applied across Australia to the appropriate population subset (age, health insurance status, SEIFA) within each statistical local area.

Accessibility

The degree of remoteness of each statistical local area was obtained from the Australian Bureau of Statistics website using the Australian Standard Geographical Classification (ASGC) Remoteness Area Correspondences, 2006. The ASGC classification divides Australia by remoteness into five groups: major cities Australia (R1), inner regional Australia (R2), outer regional Australia (R3), remote Australia (R4) and very remote Australia (R5). For SLAs that fall into two categories of ASGC classification, the group with higher percentage was chosen.

Direct costs

The Australian Refined Diagnosis Related Group (AR-DRG) version 5.1 was used to calculate the direct cost. Estimated cost of care was determined for each episode using the national standard diagnostic related group (DRG) average price. For insured individuals, out of pocket additional hospital costs were added. Three estimated levels (low, medium and high) of this additional cost were calculated, based on the data from the Australian Institute of Health and Welfare.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>The number, proportion and cost of modeled cases of third molar extraction per State per annum of Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>Insured</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>NSW</td>
<td>25,516</td>
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<tr>
<td>ACT</td>
<td>1,493</td>
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<tr>
<td>Grand total</td>
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<table>
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<tr>
<th>Table 2</th>
<th>The number, proportion and cost of third molar extraction cases per geographical area of Australia per annum</th>
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</thead>
<tbody>
<tr>
<td>Geographic area</td>
<td>Hospitalisations</td>
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<tr>
<td>Minor cities of Australia</td>
<td>19,432</td>
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<tr>
<td>Minor regional Australia</td>
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<tr>
<td>Very remote Australia</td>
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<td>Total</td>
<td>79,501</td>
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<table>
<thead>
<tr>
<th>Table 3</th>
<th>Average individual cost (Australian dollars) of third molar removal under SA</th>
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<tr>
<td>Insured</td>
<td>Non-insured</td>
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<tr>
<td>Direct hospitalisation cost</td>
<td>2,664</td>
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<tr>
<td>Additional out of pocket direct cost</td>
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<tr>
<td>Indirect cost (Absenteeism + Travel)</td>
<td>1,850</td>
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<tr>
<td>Total</td>
<td>5,664</td>
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</table>

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Average individual cost (Australian dollars) of third molar watchful monitoring strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comprehensive oral examination</td>
<td>60.3</td>
</tr>
<tr>
<td>Orthopantomogram</td>
<td>47.4</td>
</tr>
<tr>
<td>Combined cost of monitoring protocol</td>
<td>107.7</td>
</tr>
<tr>
<td>Cost for ten monitoring sessions (20 g)</td>
<td>1,077</td>
</tr>
</tbody>
</table>
Indirect cost

Loss of productivity (absenteeism) was calculated using average sick leave days associated with wisdom teeth removal under general anaesthesia, which is 5.7 days as reported by Edwards et al.6 The average cost to the economy per day was calculated as average daily earnings, which is 20% of average weekly earnings estimated by the Australian Bureau of Statistics in November 2013 at $1498.7.

Most hospitalisations for impacted teeth are performed in the major cities and patients living in R2, R3, R4 and R5 need to travel to hospital. To account for travelling days, an extra one, two and three days were allocated for patients living in R3, R4 and R5 respectively. An estimated cost for transport was allocated to each of the five geographic groups (R1 to R5). Travel cost was estimated on three levels (low, medium and high) to account for different methods of transport.

Cost calculation of watchful monitoring strategy

The watchful monitoring strategy includes a proposed plan of active surveillance over time of retained asymptomatic impacted third molars. This plan includes clinical examination and panoramic radiography every two years.14 The retention period extends for the life of the patient until wisdom teeth become symptomatic and removed, or until they fully erupt. However, to establish a cost comparison over a reasonable period, the proposed retention period included in this study was 20 years, considering initial examination at the age of 15 as a high proportion of hospitalisations for impacted teeth in Australia starts at that age.15

Average cost of comprehensive oral examination (Australia wide) was retrieved from the Australian Dental Association Fees survey for 2012.16 Panoramic imaging (bulk billed) cost was retrieved from Medicare Australia Benefits Schedule as at August 2014.17 A scenario of Australian rates dropping to UK rates was analysed. Although an Orthopantomograph (OPG) was included at every clinical visit, it would be expected that a clinician would show judgement in this decision. However, for the sake of the modelling the maximum one per clinical examination was taken.

RESULTS

Direct and indirect cost of hospitalisations

Number of cases

The estimated number of hospitalisations for impacted teeth in Australia, in 2008/2009 for the age group 15–34 years was 97,949. Insured patients accounted for 76,307 (80%) and non-insured patients for 15,642 (16%). The distribution over the States and Territories of Australia is shown in Table 1. The distribution of hospitalisation cases over the five remoteness area groups is shown in Table 2, with group R1, (major cities of Australia n = 59,433) and R2 (inner regional Australia n = 23,915) accounting for 85% of the hospitalisations.

Direct cost

The annual direct cost of hospitalisations, excluding out of pocket cost, was estimated to be 259 million with individual DKG cost of $2644 for each hospitalisation. Approximately 85% of this amount ($207 million) was paid by insured patients. Out of pocket cost, paid to hospitals by insured patients, was estimated to range between $58–156 million, with a medium calculation of $91 million. In total, the direct cost of hospitalisations ranged between $317–415 million, with the medium calculation being $350 million.

Indirect cost

Indirect cost (absenteeism and transport) was estimated to be $1,178 million (low), $1,811 million (medium) and $1,838 million (high) with average individual costs of $1,850. The total combined direct and indirect cost would range between $496 million (low), $531 million (medium) and $599 million (high). These cost figures are related to age groups 15–34 years only, which represents 80% of hospitalisations. Table 3 summarises the individual average cost of tooth removal under general anaesthesia.

Individual cost of watchful monitoring strategy

The estimated individual cost for 20 years of watchful monitoring, which includes ten clinical examinations ($60.3) and panoramic radiographs ($47.4), was $1077 (Table 4). Therefore the estimated annualised cost (noting that the recommended examinations was every two years) was $53.6, which is approximately 1% of the estimated total cost of single episode of removal.

Cost implications for the adoption of watchful monitoring

The scenario of Australian rates of hospitalisation dropping to UK rates following the adoption of the watchful monitoring strategy revealed a possible reduction by 85%, with an annual number of $3,850 individuals avoiding hospitalisation, and shifting to a watchful monitoring strategy and an annual reduction of costs ranging between $420–513 million, depending on the scenario of the calculation and inclusive of the ongoing watchful monitoring of those patients that fell outside the criteria for extraction.

DISCUSSION

Dentists are often faced with the situation of asymptomatic, disease-free impacted teeth, and are usually tempted to provide treatment for those cases. The decision between two treatment options, that is, prophylactic removal or retention, is left to the individual judgements of dentists, with the exception of the UK. There, the practice of prophylactic removal of third molars has been discouraged for nearly two decades, with clear guidelines issued by NICE in 2000 to limit third molar removal to only pathological situations, such as untreatable tooth decay, abscesses, cysts or tumours, disease of the tissues around the tooth and if the tooth is in the way of other surgery.12

The prophylactic removal of impacted wisdom teeth has been traditionally advocated in Australia and the widely provided argument was to avoid dental infections and oral cellulitis, especially at older age.16 It would be expected, following this reasoning, that the rate of submandibular cellulitis would be higher in the UK, which has 85% less wisdom tooth removals.10 It has been recently shown that this is not the case, and the actual rates of oral cellulitis in Australia was significantly higher than in the UK for the period between 1999 and 2008.19

One reason for this attitude in Australia might be that oral maxillofacial surgery is considered predominantly a dental speciality, dealing mainly with pathology in the jaws and related structures and the removal of impacted wisdom teeth, which constitute a major percentage of oral maxillofacial work in Australia.11 This is not necessarily the case in the UK, where oral maxillofacial surgery is considered more of a medical speciality with a wider scope of practice extending to pathology in the face and neck area.

The model used in our research was based on actual and projected Australian data and did not take into consideration the cost of possible complications associated with both strategies, such as post-operative infection, nerve injury/paresis in the case of removal strategy, as well as the scenario in which the disease-free wisdom tooth becomes symptomatic during the watchful monitoring period and needs removal. However, a previously published study by Edwards et al.11 in the UK used probability data for possible outcomes of both strategies which were entered into a decision tree. They concluded that, in the UK, mandibular third molar removal is less costly to the NHS, more effective for the patient and more...
cost-effective to both parties than removal.

One limitation of this study may be the accuracy of the indirect cost estimates regarding absenteeism. Absenteeism measurement is affected by different patient factors, such as being unemployed or a student, and this information was not available in the database for each case of hospitalisation. However, the Australia unemployment rate is approximately 6%, and the majority of individuals hospitalised (80%) have private health insurance, which is highly correlated to having employment. As for the age group 15–19, the Australian Bureau of Statistics states that only 4% are employed. However, it is implied that a parent or carer, who is most likely employed, will take an absence from work and stay with their child.

The results of our research reveal that the controversial practice of prophylactic asymptomatic wisdom tooth removal is responsible for an extremely high expenditure by Medicare, insurance companies and individuals, as well as a considerable loss of productivity. An alternative watchful monitoring strategy was shown to be more cost effective with minimal annual cost.

The UK experience with NICE guidance since 1999 has been very positive, and although the overall number of removal of third molar episodes has decreased significantly, there has been a slow increase in the number of episodes since 2005, mostly due to caries to adjacent teeth and at an older age. A criticism of NICE guidelines by Mavers et al. in 2014 was that the recommended standard routine programme of dental care for asymptomatic, disease-free impacted third molars, is not straightforward when it comes to radiographic examination, as bitewing and peral radiographs are usually not helpful for radiographic examination of wisdom teeth. A more focused surveillance for adjacent caries was also recommended by Renton et al. in 2012.

The proposed watchful monitoring strategy, including an OPG every two years and a thorough clinical examination for periodontal pockets and caries, would be an improved version of the NICE prescription.

In conclusion, with no evidence to support or refute the prophylactic removal of asymptomatic wisdom teeth, proposed watchful monitoring strategy is a more cost effective alternative in the Australian context.

Appendix 11 (Published Article)

A 10-year retrospective analysis of hospitalisation for oral cellulitis in Australia: the poor suffer at 30 times the rate of the wealthy by Abed Aktam Anjrini, Estie Kruger and Marc Tennant

The aim of this study was to investigate the trends of hospitalisation for cellulitis in Western Australia. There was a strong association between socioeconomic status and rate of cellulitis, with the most disadvantaged quintile of the population (1.7% of residents) accounting for 34% of cellultes cases. Aboriginal and Torres Strait Islander people were almost seven times over-represented, compared with non-Indigenous Western Australians.

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Introduction
Cellulitis of the floor of the mouth and submandibular region is a rare condition that mostly (80%) develops as a result of cortico-pulpal necrosis and/or periodontitis-periostitis associated with unerupted and partially erupted teeth. The most serious clinical presentation of this cellulitis is Ludwig Angina, a potentially fatal, rapidly spreading soft-tissue infection with a tendency to cause necrosis, distortion, and obstruction of the airway. In most cases of cellulitis hospital admission is required to drain the pus and remove the cause.

Cellulitis of the mouth and submandibular region can be used as an indicator of significant dental disease in a society. As a measure of the extreme level of dental disease at a population level, it can provide indicators of disease burden and the general dental service uptake, as good general dental health will mitigate the risk factors that can lead to cellulitis. Against this backdrop an analysis of the incidence and distribution of mouth and submandibular cellulitis (for the rest of this study described as cellulitis) is a good measure of a community's global oral health.

Western Australia is the largest geographic state in Australia, with a total population approaching 2 million people. Of this total population about 1.6 million live in the major capital city, Perth. Western Australia is a relatively wealthy community with a high GDP and a strong public health system. Safety net dental services for the poor augment a strong private general dental network. More than 80% of all dental services are provided in the private sector on a fee-for-service basis. People in poverty can access government subsidised care. The state also provides universal coverage for school-age children. With this robust service model it would be expected that the level of cellulitis would be low with respect to comparable situations and the rate would be expected to be stable over time. The aim of this study was to investigate the trends of hospitalisation for cellulitis in Western Australia.

Method
Hospitalisation data
De-identified clustered data was obtained from the statewide hospital morbidity data system under the ethics approval of The University of Western Australia. Gender, age, place of residence (Statistical Local Area (SLA)), indigenous status, type of hospital admitted to, insurance status, and Diagnostic Related Group (DRG) cost estimates for the procedure comprised the data frameset. Data for analysis was obtained from Western Australian Hospital Morbidity Data System (WAMDS) for 10 financial years, from 1999–2000 to 2008–2009. The principal diagnosis, classified by the international classification of disease (ICD-10AM) system, was obtained for every patient diagnosed with the condition ‘K12.2: Cellulitis and Abscess of the Mouth’ and discharged from any private and public hospital in Western Australia during the study period. Code K12.2 is mainly applicable to cellulitis of floor of mouth and submandibular abscess, while other jaw cellulitis cases are classified under code L09.201 and were not included in this study.

Population data
Population data was derived from 2006 census data collected by the Australian Bureau of Statistics. It was extracted from the online census data clustered by SLA to match the clustering of the hospitalisation data.

Socioeconomic indicators
The Socioeconomic Indexes for Areas (SEIFA) index is the nationally accepted coding for socioeconomic advantage and disadvantage in Australia and is developed by the Australian Bureau of Statistics. SEIFA uses a broad definition of relative socioeconomic disadvantage in terms of community access to resources and the ability to be part of society. SEIFA represents an average of all people living in an area but it does not represent the situation of each person. Thus SEIFA is only a relative measure, not an absolute measure of socioeconomic disadvantage. There are four indexes under SEIFA concerning different aspects of
the socioeconomic conditions of people. For the purposes of this study the SEIFA Index of Relative Socio-Economic Disadvantage (IRSD) was used, as this index focuses primarily on disadvantage. This study has clustered the patients according to SEIFA quintiles from the poorest of the population (Group 1) through to the most advantaged group of the population (Group 5).

**Results**

**General description statistics**

There were a total of 762 patients hospitalised in Western Australia for cellulitis during the 10-year period 1999–2009. More males (50.8%) than females (40.2%) were hospitalised. The mean length of stay in hospital was 3.1 days (SD=3.7) and the average DRG cost estimate was $6,997 (SD=$17,013). The number of patients admitted to hospital for this condition per year almost doubled over the study period from 1999–2000 to 2008–2009, with the peak age group being between 20–35 years old (Figure 1).

**Remoteness and socioeconomic**

Remote and very remote dwelling people made up some 14.5% of the total cases of hospitalisation for oral cellulitis, while only representing 7.1% of the population. A consistent trend was not evident in remoteness, although remote area dwelling people had the highest rates of hospitalisation (Figure 2). The analysis of the effect of socioeconomic status found that the most disadvantaged group of the population (Group 1), despite being 1.7% of the Western Australian population, accounted for 34% of cellulitis cases. This indicates that they are 20 times more prone to cellulitis than their predicted level based on the rest of the population. Group 2 (7.7% of WA population) had 19% of cellulitis episodes, being three times higher than the highest SEIFA group. While Group 3 (38.8% of WA population) suffered 18% cellulitis and Group 4 (26.9% of population) had only 14% cellulitis. Finally, Group 5 (the most affluent group of WA society), which is a little over a quarter of the population, accounted for just 13.7% of all cellulitis cases. Adjusting for population size, the poorest quintile of the population were 7–10 times more likely to be hospitalised than the rest of the population (Figure 3).

**Comparison to England**

Comparing the rates (per million) of hospitalisation for cellulitis during the decade in question between England and Western Australia, it was found that in Western Australia the rates were significantly higher for all years of the study (Figure 4).
Australia’s Aboriginal people [have] a life expectancy some 10–20 years shorter [...] and a rate of cellulitis among the poor at some 20 times the rest of the population.
It is also of interest that the rates of cellulitis in Western Australia are, year-on-year, higher than that of the UK. This international comparison (with a comparable country) provides an interesting basis for further research examining the factors at play. Already research from the UK has noted that the number of admissions as a result of odontogenic infections have increased most among poorer people in the UK, which is consistent with our findings although at an overall lower rate. This may point to a similar story, but of greater poverty, in Western Australia or other factors such as population distribution and service accessibility may be at play. Research from India has shown the influence of socioeconomic factors on deep neck infections that are mostly of dental origin. It is clearly evident that cellulitis and poverty are linked and international trends support the findings in Western Australia. A clear exemplar in our data is the linkage between cellulitis and Australia’s Aboriginal people. The poverty experienced by this marginalised group is well documented and leads to an overall health situation that culminates in a life expectancy some 10–20 years shorter than the rest of the population. Our findings of a rate of cellulitis among the poor at some 20 times the rest of the population continue the misery of the story presented.

The data highlight the need for focused addressing of poverty at population level (and, in our case, specifically the correlation between oral health and poverty). The linkage between disease burden and poverty is a near universal health, social and economic conundrum of the 21st century. Efforts to diminish poverty (and its ensuing social divide) in all societies throughout time have and will continue to be vital to advancements in the health of the population.

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