ORIGINAL REPORT: EPIDEMIOLOGIC RESEARCH

Reducing Potentially Preventable Dental Hospitalizations of Young Children: A Community-Level Analysis

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Abstract: *An increasing number of Australians are being admitted to hospitals and day procedure centers to have dental treatment under a dental general anesthetic (DGA). Children younger than 2 y are having DGAs. These operations are costly and, although there have been improvements in safety, are not without risk. Most DGAs in children are to treat dental caries and have been defined as potentially preventable dental hospitalizations (PPDHs). This article reports on an analysis of the impact of access to community water fluoridation (CWF), availability of oral health professionals (OHPs), and socioeconomic status (SES) on PPDHs of 0- to 4-y-olds in 2012–2013 in Victoria, Australia. Data on these variables were obtained at the community (postcode) level. From the negative binomial multivariate analysis, each of the 3 independent variables was independently significantly associated with PPDHs at the postcode level. Children residing in postcodes without CWF on average had 59% higher rates than those with access*

(incident rate ratio [IRR], 1.59; $P < 0.0001$), children in postcodes with the lowest level of availability of OHPs had 65% higher rates than those with the highest access (IRR, 1.65; $P < 0.0001$), and children living in the most disadvantaged SES quintiles had 57% higher rates than children in the most advantaged quintiles (IRR, 1.57; $P < 0.0001$). There was a stepwise social gradient by SES quintile. In analysis of access to CWF and SES status, children without access to CWF had 86% higher PPDH rates than children with access (IRR, 1.86; $P < 0.0001$). In summary, no access to CWF, poor availability of OHPs, and lower SES status were independently associated with higher PPDH rates among 0- to 4-y-olds in Victoria at the postcode level. The study highlights the importance of considering 3 interacting factors—access to CWF, access to OHPs, and SES—in efforts to reduce PPDH rates in young children.

Knowledge Transfer Statement: *Extending access to water fluoridation, increasing the availability of dental*

services, and raising disadvantaged families' socioeconomic status are each likely to decrease the rate of dental general anesthetics in young children.

Keywords: anesthesia, fluoride(s), health services research, hospital dentistry, prevention, caries

Introduction

The number of dental general anesthetics (DGAs) performed in Australia has increased. In 2013–2014, there were 130,792 DGAs, a rate of 5.9 per 1,000 population (Australian Institute of Health and Welfare [AIHW] 2016a). This has been a 6% increase in DGAs since 2007–2008. In Australia, most DGAs are generally undertaken in hospitals or day procedure centers rather than in dental clinics because of strict occupational health and safety regulations.

Children as young as 1 y are being admitted to have teeth extracted or filled under general anesthesia (Butt 2015). High rates of children's DGAs have also been reported in Canada (Schroth

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et al. 2014), England (Deery et al. 2015; Shepherd and Ali 2015), and New Zealand (Whyman et al. 2014).

Hospitalization and DGA procedures are expensive as they require payment for the clinical operators, medical staff, and a facility fee. Although there have been improvements in safety through newer drugs and better monitoring, DGAs entail mortality and morbidity risks.

Potentially preventable dental hospitalizations (PPDHs) are a subset of DGAs where hospitalization is considered to have been avoidable through primary prevention of oral disease or if timely and adequate nonhospital care had been provided (AIHW 2015a). These hospitalizations have also been called potentially avoidable dental hospitalizations or dental ambulatory care-sensitive conditions based on work done by Billings, Weissman, and colleagues in the United States (Billings and Hasselblad 1989; Weissman et al. 1992; Billings et al. 1993) in the 1980s. PPDHs are defined by the principal diagnosis of admission.

PPDHs are the highest cause of all potentially preventable hospitalizations (PPHs) of children and young adults living in Victoria, Australia. Data on PPHs are available from the Victorian Health Information Surveillance System (VHISS), an interactive website displaying public health indicators (Department of Health and Human Services 2017). These data are extracted from the Victorian Admitted Episode Dataset (VAED), which contains information on all admissions in Victorian public and private hospitals and day procedure centers. PPDH rates are higher than PPH rates for asthma and diabetes. About 15,000 Victorians are admitted each year for PPDHs, half of them under 25 y age. Most are younger than 10 y, with the main diagnosis for this younger age group being dental caries (Department of Health and Human Services 2017). This means that most DGAs in this age group are PPDHs.

PPHs, including PPDHs, are being used in Australia as a performance measure of the health system (AIHW 2015b).

Reducing PPHs is a specific objective in health care reform, with the aim of improving patients' outcomes, reducing pressure on hospitals, and enhancing health system efficiency and cost-effectiveness (Katterl et al. 2012). The direct and indirect costs of PPDHs are a further performance measure for the health system.

A range of factors have been identified that affect DGAs and PPDHs in children. Ramdaw and colleagues (2017) determined that demographic, socioeconomic, behavioral, and clinical factors were associated with DGA use among British children. Australian studies have shown that child PPDH rates are associated with low socioeconomic status (SES) (Department of Human Services [DHS] 2007; Rogers and Morgan 2012; Butler et al. 2013), no access to community water fluoridation (CWF) (DHS 2007), and residence in geographically remote locations where there is limited availability of oral health professionals (OHPs) (AIHW 2016a). The impact on child DGAs of CWF and SES has been shown in 3 published studies: in Israel among under 18-y-olds (Klivitky et al. 2015) and in studies in England among under 5-y-olds (Public Health England 2014; Young et al. 2015). These studies did not focus on PPDHs or control for availability of dental care.

The aim of the study was to verify the association between access to CWF, availability of OHPs, and SES on PPDHs of young children at the community level in Victoria. These 3 factors were chosen because they have been shown to have associations with dental hospitalizations in the studies cited above and because findings may have policy implications. The focus was on young children because of their relatively high PPDH rates and the possible health risks and family and community costs of DGAs.

Materials and Methods

The dependent variable for analysis was PPDH rates, with access to CWF, availability of OHPs, and SES as the 3 independent variables. Gender was not

included as a variable because gender differences for 0- to 4-y-old PPDH rates are small (DHS 2007). The geographical level of analysis for each of the variables was the postcode. This was the smallest geographical area possible to achieve the most accurate correlation between the 3 independent variables and PPDH rates.

Information on the PPDHs of Victorian 0- to 4-y-olds in 2012–2013 was obtained from the VAED. Rates of PPDHs for 0- to 4-y-olds were generated at the postcode level using Australian Bureau of Statistics estimated resident population counts based on the 2011 national census and expressed per 1,000 population.

PPDH cases were identified using the principal diagnosis codes from the *International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification (ICD-10-AM)* that are acknowledged as being potentially preventable in Australia by the AIHW (AIHW 2016a). These principal diagnosis codes are listed in Table 1. Conditions considered not preventable are excluded—for example, disorders of tooth development, cleft lip and palate conditions, and extraction of embedded or impacted teeth such as wisdom teeth.

For access to CWF, postcodes were designated “fluoridated” if the population had access to a water supply with a fluoride concentration of at least 0.7 parts per million. In “nonfluoridated” postcodes, the fluoride concentration was below 0.7 ppm. In 10 of the 344 postcodes, not all towns were fluoridated. If the majority of the population in the postcode had access to fluoridated water, those postcodes were designated “fluoridated.” Data were obtained from the Department of Health and Human Services for 2008. The year 2008 was used to allow for all 0- to 4-y-olds in 2012–2013 to have potentially experienced a lifelong benefit of the preventive impact of fluoridation on dental caries.

Rates of OHPs were calculated at the postcode level from the main practice addresses of registered dentists, oral and dental health therapists, and dental

Table 1.Principal Diagnosis Codes for Dental Hospitalizations Used in Victoria—*ICD-10-AM* Codes.

Code	Description
Dental conditions considered potentially preventable	
K02	Dental caries
K03	Other diseases of hard tissues of teeth
K04	Diseases of the pulp and periapical tissues
K05	Gingivitis and periodontal disease
K06	Disorders of gingival and edentulous alveolar ridge
K08	Other disorders of teeth and supporting structures
K09.8	Other cysts of oral region, not elsewhere classified
K09.9	Cysts of oral region (unspecified)
K12	Stomatitis and related lesions
K13	Other diseases of lip and mucosa
Dental conditions not considered potentially preventable	
K00	Disorders of tooth development and eruption
K01	Embedded and impacted teeth
K07	Dentofacial anomalies (including malocclusion)
K09.1	Developmental (nonodontogenic) cysts of the oral region
K09.2	Other cysts of the jaws
K10	Other diseases of the jaws
K11	Diseases of salivary glands
K14	Diseases of the tongue
K09.0	Developmental odontogenic cysts

ICD-10-AM, International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification.

hygienists obtained from the Australian Health Practitioner Registration Agency. Pediatric dentists were not included because the focus was on primary rather than specialist dental care. Access to OHPs was categorized into 3 equal frequency groups: lowest access, <2 registered OHPs per 1,000 population (113 postcodes); medium access, 2 to <7.4 OHPs per 1,000 population (114 postcodes); and highest access, ≥7.4 OHPs per 1,000 population (117 postcodes). Rates of OHPs were used as a proxy for accessibility of dental services.

SES was assessed from a composite measure, the Index of Relative Socioeconomic Disadvantage (IRSD), sourced from the 2011 national census (Australian Bureau of Statistics 2017). The IRSD attributes scores of disadvantage to local areas based on a composite of characteristics such as low income, low educational attainment, high unemployment, and employment in relatively unskilled occupations. The IRSD is widely used in public health reports such as *Australia's Health 2016* (AIHW 2016b). The score indicates the collective socioeconomic characteristics

of the people living in an area, with a low score indicating a high proportion of relatively disadvantaged people. IRSD scores are presented in quintiles, with quintile 1 (Q1) being the most disadvantaged quintile and quintile 5 (Q5) being the most advantaged quintile.

Descriptive analysis was undertaken, and the significance of associations between the 3 independent variables and PPDH rates was determined using negative binomial bivariate and multivariate regression. Negative binomial regressions were used as the dental hospitalization data were counts of admissions, and significant overdispersion was identified compared to Poisson regressions. Two multiple regression models were developed. Model 1 included each of the 3 independent variables. Model 2 included only access to CWF and SES to determine their relative impact on PPDH rates. This allowed comparison of results with the international studies that only investigated CWF and SES. Incident rate ratios (IRRs) were generated—these are the ratio of incidence rates and show relative rates of variables. Statistical analyses were undertaken using Stata 12.1 (StataCorp). Statistical significance was set at $P < 0.05$.

Results

Descriptive statistics of the 3 independent variables (access to CWF, access to OHPs, and SES), by distribution of postcodes, the number of PPDHs, and PPDH rates, are shown in Table 2. There were 1,297 PPDHs among 318,997 children aged 0 to 4 y living in 344 postcodes, which translates to a PPDH rate of 4.07 children per 1,000 population.

A total of 210 postcodes (61%) were fluoridated. Almost 70% of children who had a PPDH resided in these fluoridated postcodes. Most children who had a PPDH lived in postcodes where there was medium access to OHPs (602, 46.4%), with 252 (19.4%) children from lowest access postcodes and 443 (34.2%) from highest access postcodes. The highest proportion of children who had a PPDH (302, 23.3%) lived in the lowest SES quintile, Q1.

Table 2.

Descriptive Statistics and Negative Binomial Weighted Rates of PPDHs of 0- to 4-y-Old Children by Access to Water Fluoridation, Availability of Oral Health Professionals, and Socioeconomic Status, in 2012–2013, Victoria.

Independent Variables	Postcodes (<i>n</i> = 344), <i>n</i> (%)	PPDHs (<i>n</i> = 1,297), <i>n</i> (%)	No. of Children (<i>n</i> = 318,997)	PPDH Rate per 1,000 (95% CIs) (Weighted)
Access to fluoridation				
Fluoridated	210 (61.0)	907 (69.9)	260,686	3.31 (3.01–3.61)
Nonfluoridated	134 (39.0)	390 (30.1)	58,311	6.86 (5.85–7.86)
Access to oral health professionals				
Lowest access	113 (32.8)	252 (19.4)	36,415	8.07 (6.47–9.68)
Medium access	114 (33.1)	602 (46.4)	157,154	3.63 (3.00–4.27)
Highest access	117 (34.0)	443 (34.2)	125,428	3.42 (2.89–3.95)
Socioeconomic status				
Q1 (most disadvantaged)	51 (14.8)	302 (23.3)	47,346	6.09 (5.11–7.06)
Q2	61 (17.7)	227 (17.5)	49,222	4.92 (3.83–6.02)
Q3	53 (15.4)	242 (18.7)	55,769	4.38 (3.48–5.28)
Q4	88 (22.6)	281 (21.7)	88,288	3.19 (2.65–3.73)
Q5 (most advantaged)	91 (26.5)	245 (18.9)	78,372	3.11 (2.61–3.62)

PPDH, potentially preventable dental hospitalizations; Q, quintile.

From the bivariate negative binomial analyses, PPDH rates of children in nonfluoridated postcodes (6.86 per 1,000 population) were twice as high as those in fluoridated postcodes (3.31; $P < 0.0001$) (see Table 2). Children in the lowest access to OHPs postcodes had over twice higher PPDH rates (8.07 per 1,000 population) than children living in medium (3.63; $P < 0.0001$) and high (3.42; $P < 0.0001$) access postcodes. Rates of PPDHs followed a social gradient: Q1 (6.09), Q2 (4.92), Q3 (4.38), Q4 (3.19), and Q5 (3.11). Children living in the lowest SES postcodes (Q1) had significantly higher PPDH rates than children residing in the second highest (Q4) and highest (Q5) SES postcodes, $P < 0.0001$. Rates for children in the lowest SES postcodes had almost twice the PPDH rates of children in the most advantaged postcodes—6.09 compared to 3.11 per 1,000 population.

Unadjusted (crude) and adjusted IRRs for each of the 3 independent variables are shown in Table 3. The

unadjusted and adjusted rates were calculated by bivariate and multivariate negative binomial regression analyses, respectively. Unadjusted IRRs varied about 2-fold for each of the 3 independent variables—children living in nonfluoridated compared to fluoridated postcodes (2.07, $P < 0.0001$), those in the lowest access to OHPs postcodes compared to highest access (2.36, $P < 0.0001$), and children living in the most disadvantaged compared to the most advantaged postcodes (1.95, $P < 0.0001$).

Adjusted IRRs for 2 models are also shown in Table 3. Model 1 includes the 3 independent variables. Each of the 3 variables was independently significantly associated with PPDH rates, $P < 0.0001$. Children living in postcodes without access to CWF had 59% higher rates than those with access (IRR, 1.59; $P < 0.0001$), children in postcodes with the lowest level of access to OHPs had 65% higher rates than those with the highest access (IRR, 1.65; $P < 0.0001$), and children living in the most disadvantaged SES

quintile postcodes had 57% higher rates than children in the most advantaged quintile (IRR, 1.57; $P < 0.0001$). There was a stepwise social gradient by SES quintile apart from a nonsignificant higher rate in children living in Q5 compared to Q4 postcodes.

Analysis of access to CWF and SES status on PPDH rates was tested in model 2. Both variables were independently significantly associated with PPDH rates, $P < 0.0001$. Children without access to CWF had 86% higher PPDH rates than children with access (IRR, 1.86; $P < 0.0001$), equating to 46% lower PPDH rates in fluoridated postcodes. Children living in the most disadvantaged SES quintiles had 62% higher rates than children in the most advantaged quintiles (IRR, 1.62; $P < 0.0001$).

Discussion

Each of the variables—access to CWF, availability of OHPs, and SES—was independently associated with

Table 3.

Negative Binomial Regression between Potentially Preventable Dental Hospitalizations and Access to Water Fluoridation, Availability of Oral Health Professionals, and Socioeconomic Status for 0- to 4-y-Old Children by Postcode, Victoria, 2012–2013.

Independent Variables	Unadjusted		Adjusted			
			Model 1		Model 2	
	IRR (95% CI)	P Value	IRR (95% CI)	P Value	IRR (95% CI)	P Value
Access to fluoridation						
Fluoridated ^a	1.00		1.00		1.00	
Nonfluoridated	2.07 (1.75–2.45)	<0.0001	1.59 (1.32–1.90)	<0.0001	1.86 (1.57–2.20)	<0.0001
Access to oral health professionals						
Highest access ^a	1.00		1.00			
Medium access	1.06 (0.88–1.28)	0.53	0.98 (0.84–1.14)	0.8		
Lowest access	2.36 (1.92–2.90)	<0.0001	1.65 (1.31–2.08)	<0.0001		
Socioeconomic status						
Q5 (most advantaged) ^a	1.00		1.00		1.00	
Q4	1.03 (0.82–1.28)	0.83	0.93 (0.76–1.13)	0.45	0.95 (0.77–1.16)	0.59
Q3	1.41 (1.09–1.81)	0.0077	1.21 (0.97–1.50)	0.088	1.22 (0.97–1.53)	0.089
Q2	1.58 (1.21–2.06)	0.0007	1.32 (1.03–1.68)	0.026	1.36 (1.09–1.71)	0.0078
Q1 (most disadvantaged)	1.95 (1.56–2.45)	<0.0001	1.57 (1.27–1.95)	<0.0001	1.62 (1.31–2.00)	<0.0001

IRR, incidence rate ratio.

^aReference category.

PPDH rates in the 0- to 4-y-old age group studied. While causality cannot be claimed as the study was cross-sectional, the results are consistent with strong broader evidence. There is strong evidence of the preventive effect of CWF on dental caries prevalence (National Health and Medical Research Council 2017), which is relevant as the principal diagnosis for 90% of the participants who had a PPDH was dental caries. The social gradient found in PPDH rates is consistent with the large body of research in more economically developed communities that shows such a gradient in the prevalence of dental caries (Watt et al. 2016). The association found with access to OHPs is consistent with the concept of PPDHs.

The finding of a 46% lower PPDH rate in 0- to 4-y-olds living in fluoridated compared to nonfluoridated postcodes,

when adjusting for SES, is similar to that reported in recent studies. In England, lower dental hospitalization rates of 45% and 55%, when adjusting for deprivation, were found in 1- to 4-y-olds living in fluoridated areas compared to nonfluoridated areas (Public Health England 2014; Young et al. 2015). In addition, Klivitsky and colleagues (2015) found a 53% lower dental hospitalization rate in 0- to 18-y-olds living in fluoridated compared to nonfluoridated Israeli cities. Greater differences were found in cities with lower SES. A New Zealand review of benefits and costs of water fluoridation found there was a 48% reduction in hospital admissions for treatment of tooth decay in children aged up to 4 y living in fluoridated communities (Moore and Poynton 2015). No studies were identified that controlled for the 3 variables used in the current

study: access to CWF, availability of OHPs, and SES.

The association found between PPDH rates and availability of OHPs was as strong as with the 2 other variables as shown in model 1, Table 3 (IRR, 1.65; $P < 0.0001$). The OHPs included dentists, dental therapists, and dental hygienists. Dentists were the highest proportion of OHPs at 88%. Availability of OHPs as a proxy for access to dental services was included in the model because of the concept that PPHs may be prevented if there is primary prevention or access to primary health care before hospitalization is required.

Support for access to CWF and increased access to dental services being causally linked to PPDH rates comes from Victorian trend data for PPDH rates of 0- to 4-y-olds between 2001–2002 and 2012–2013. Over this period, PPDH rates

for this age group progressively reduced by 52% (Department of Health and Human Services 2017). The reduction coincided with an increase in the proportion of Victorians able to access CWF (from 76% to 90%) (Neil 2011) as well as an increase in the number of 0- to 4-y-olds who received public dental care (from less than 5,000 to almost 30,000 a year) (Department of Health and Human Services, unpublished data). As noted, earlier access to dental care can allow caries to be managed before the need for a DGA.

PPDHs rates of young children can be a useful performance measure of the impact on dental caries of both primary prevention and health service systems. This is because over 90% of admissions are for dental caries. Using PPDH rates of over 10-y-olds as a performance measure requires review because about half of admissions are for the treatment of caries and the remainder are for other diseases of the teeth and supporting structures (AIHW 2017). Treatment for the latter may include extraction of teeth for orthodontic reasons, which can be questioned as preventable.

A strength of the study was that data on all 0- to 4-y-old PPDHs in public and private hospitals and day procedure centers for 2012–2013 in Victoria were analyzed. In addition, multivariate analyses of 3 key variables for PPDHs were conducted at a small area level (postcode).

The main limitations of the study were that it was a cross-sectional and ecological-level analysis, giving results at a population level and potentially not detecting results for the individual (the ecological fallacy). Analysis at the smallest geographic level possible of postcode reduced the risk of this occurring.

In relation to a child's access to community water fluoridation, the data are a point-in-time measure and do not give an indication of the child's lifetime exposure to community water fluoridation. This is not likely to have significantly affected the results as the age range of the group studied was small

(5 y), but children may have moved from nonfluoridated to fluoridated postcodes and vice versa.

The models considered just 3 of the range of variables that are known to be associated with DGAs/PPDHs. Addition of other variables such as clinical factors, sugar consumption, and dental anxiety would have increased the accuracy of the models, but these data were not obtainable at the postcode level. Moreover, the focus of this study was on determining the relationship between 3 variables over which there is some public policy influence so as to identify policy implications.

Policy implications of the findings of the study are that initiatives that prevent dental caries need to be considered as over 90% of the children were hospitalized because of caries. Support is needed to address the social determinants of dental caries that lead to a social gradient in oral health (Watt et al. 2016), including in PPDH rates. Raising disadvantaged families' SES, improving the geographic availability of OHPs, and extension of CWF are all likely to decrease PPDHs in young children.

Conclusion

In multivariate analyses, access to CWF, availability of OHPs, and SES were each independently associated with PPDHs of 0- to 4-y-olds in 2012–2013. There appears to be a dynamic relationship between these factors that requires greater exploration. Extension of CWF, improving the geographic availability of OHPs, and raising disadvantaged families' SES are all likely to decrease PPDHs in young children.

Author Contributions

J.G. Rogers, contributed to conception, design, data acquisition, analysis, and interpretation, drafted and critically revised the manuscript; G.G. Adams, contributed to conception, design, data acquisition, analysis, and interpretation, critically revised the manuscript; F.A.C.

Wright, M.V. Morgan, contributed to conception, design, data analysis, and interpretation, critically revised the manuscript, K. Roberts-Thomson, contributed to data analysis and interpretation, critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work.

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