Mortality and Morbidity in Office-Based General Anesthesia for Dentistry in Ontario

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Our objective was to estimate the prevalence of mortality and serious morbidity for office-based deep sedation and general anesthesia (DS/GA) for dentistry in Ontario from 1996 to 2015. Data were collected retrospectively in 2 phases. Phase I involved the review of incidents, and phase II involved a survey of DS/GA providers. In phase I, cases involving serious injury or death for dentistry under DS/GA, sourced from the Office of the Chief Coroner of Ontario and from the Royal College of Dental Surgeons of Ontario (RCDSO), were reviewed. Phase II involved a survey of all RCDSO-registered providers of DS/GA in which they were asked to estimate the number of DS/GAs administered in 2015 and the number of years in practice since 1996. Clinician data were pooled to establish an overall number of DS/GAs administered in dental offices in Ontario from 1996 to 2015. Prevalence was calculated using phase I (numerator) and phase II (denominator) findings. The estimated prevalence of mortality in the 20-year period from 1996 to 2015 was 3 deaths in 3,742,068 cases, with an adjusted mortality rate of 0.8 deaths per 1 million cases. The estimated prevalence of serious morbidity was 1 injury in 3,742,068 cases, which adjusts to a serious morbidity rate of 0.25 per 1 million cases. The mortality rate found in this study was slightly lower than those published by earlier studies conducted in Ontario. The risk of serious morbidity was found to be low and similar to other studies investigating morbidity in office-based dental anesthesia.

Key Words: Morbidity and mortality; Dental anesthesia; Deep sedation; General anesthesia.

Dentists require patient cooperation for a dental appointment to be successful. There are many instances in which a patient finds it difficult or is unable to permit dental treatment. This situation may be due to various factors including anxiety/phobia, precooperative children, cognitive impairment, lack of efficacy of local anesthetic, limited mouth opening, or the presence of syndromes or other medical comorbidities.[1] Various levels of sedation may be necessary to ensure compliance with dental treatment, including minimal sedation, moderate sedation, deep sedation (DS), or general anesthesia (GA).

There is a lack of recent data regarding morbidity and mortality events related to DS/GA for dentistry in Ontario, Canada's most populous province. Specifically, data are lacking for adverse events outside of hospital settings in terms of the number of deaths (mortalities) or severe injuries (morbidities) that occur in dental offices or surgicenters in relation to the number of DS/GAs provided in these ambulatory care settings. Morbidity and mortality reports are fundamental as they provide insight into incidents leading to patient harm and help to identify modifiable factors that allow for improvements in patient care.[2] The prevalence of mortality for dentistry under DS/GA in Ontario was last investigated

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This work was previously presented at the following conferences: poster presentation at American Society of Dentist Anesthesiologists Annual Scientific Session, Fort Lauderdale, Florida; oral presentation at Canadian Association of Dental Public Health Dentistry/Ontario Association of Public Health Dentistry Conference, Toronto, Ontario, Canada; poster presentation at American Dental Society of Anesthesiology Annual Conference, Las Vegas, Nevada; oral presentation at American Association of Dental Research Annual Meeting and Exhibition, Fort Lauderdale, Florida.

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2 decades ago by Nkansah et al.[3] Since that time, studies have shown increased use and availability of monitoring devices that may contribute to patient safety. For example, D'Eramo[4] and D'Eramo et al[5] reported an increase in the use of pulse oximetry by almost 20% over a 12-year span. The introduction of capnography as a routine monitor has also greatly improved ventilation monitoring. This may influence the prevalence of critical incidents, especially those of a respiratory nature. In addition, the prevalence of serious morbidity in the Ontario patient population undergoing DS/GA for dental treatment is yet to be established. Documenting and describing any critical incidents that occur is an important evidence-based approach to modifying practice in ways that could enhance safety.[6] The publication of the types of morbidity occurring in outpatient dental anesthesia in Ontario may aid clinicians in identifying issues in practice that could lead to harm, and potentially prevent them from occurring. Estimating the prevalence of mortality and serious morbidity for office- and surgicenter-based DS/GA for dentistry in Ontario also represents valuable information to clinicians as part of the informed consent process from patients.

The primary objective of this study was to estimate the mortality rate for office- and surgicenter-based anesthesia for dentistry in Ontario. A secondary objective of this study was to estimate the prevalence of serious morbidity within the same ambulatory care settings.

MATERIALS AND METHODS

Data were collected retrospectively in 2 phases. Phase I involved the review of incidents, and phase II involved a survey of DS/GA providers. In phase I, cases involving serious injury or death for dentistry under DS/GA were sourced from the Office of the Chief Coroner of Ontario (OCCO) and from the Royal College of Dental Surgeons of Ontario (RCDSO). Following approval by the Research Ethics Board at the University of Toronto (Approval Protocol #33203), an official written letter of request for research was sent to the OCCO and RCDSO outlining the aim and methods of the study. Cases or claims within the database or registry of these organizations that occurred in the timespan from 1996 to 2015 reporting deaths or serious morbidity related to DS/GA were requested. The organizations arranged their own internal teams to supervise the data collection process, and relevant reports were disclosed to the principal investigator (PI).

The OCCO used their electronic database to conduct their search. This electronic database was established in 2002, and thus the OCCO was unable to search for any cases that would have occurred in the period from 1996 to 2002. The OCCO used the keywords *dental*, *dental surgery*, *dental extractions*, and *GA* to search for files that would be of interest to the investigators. In order to protect the privacy of the patients and clinicians involved, complete case files extracted from the database were provided to the PI (A.E.),with any identifying information redacted. All case files were reviewed on site and extracted into a standardized template noting the following key parameters: patient demographics, medical history, dental procedure, care providers present and their clinical credentials, the anesthetic technique used, sedative agents that were administered, the critical incidents, clinical cues of an impending critical incident, and the clinical outcome.

There were 2 internal teams from the RCDSO. One team reviewed the records in the Professional Liability Program's (PLP's) database. The PLP provides professional liability insurance to all dentists in the province of Ontario. The second team reviewed the records in the Professional Conduct and Registry Affairs (PCRA) database. The teams conducted a manual search of the registry to locate files involving DS/GA from 1996 to 2016. Cases were reviewed on site by the internal research team only. Redacted summary information regarding cases where DS/GA was administered for a dental procedure were forwarded in a narrative form by the RCDSO internal research team to the PI. Upon request, the internal research teams further extracted pertinent data of relevant cases. All cases were summarized into the same standardized template. Past studies retrospectively reviewing morbidity and mortality found a standardized tool to be beneficial in the review of cases to ensure that all elements of the case that may have contributed to the outcome were captured and represented in the data set.[7] Cases that were forwarded by the organizations to the research team were reviewed to establish if they met inclusion criteria. The inclusion criteria are listed in Table 1.

Phase II involved a mail-based survey of registered providers of DS/GA in Ontario. All health care practitioners who had been approved by and registered with the RCDSO to administer DS/GA in the dental setting were recruited for this study. These clinicians included dentist anesthesiologists, oral and maxillofacial surgeons, and qualified physicians. The list of dentist and physician providers who can administer DS/GA is searchable on the RCDSO Web site, accessible via member login. As the PI is an RCDSO member, the information of registered DS/GA provider names and addresses were easily and reliably obtained. Clinicians were asked 4 questions. First, they were asked to what provider group they belonged. Second, they were asked

Table 1. Case Inclusion Criteria

Mortality Data	*Morbidity Data*
Must be in outpatient dental setting	Must be in outpatient dental setting
Deep sedation or general anesthesia administered	Deep sedation or general anesthesia administered
Occurred within 30 days postoperatively	Occurred within 30 days postoperatively
Death is reasonably certain to be caused by anesthesia or factors under the control of the clinician administering anesthesia	Must be considered within the spectrum of "serious morbidity" (injury that is permanent)

to estimate the number of DS/GAs administered by answering the question, "In the 12-month period from January 1, 2015–December 31, 2015, how many deep sedations/general anesthetics did you administer?" This question was worded to ensure that DS and GA providers would not include conscious or moderate sedation cases in their estimate. Third, clinicians were asked what method they used to estimate the number of anesthetics administered in 2015, and reported whether they used (a) computer data from the whole year, (b) computer data from an average month and multiplied the number of anesthetics by 12, (c) a manual count of the whole year, (d) a manual count of an average month multiplied by 12, or (e) another method. Last, they were asked how many years they had been practicing dental anesthesia since 1996. The aim of data gathered from survey responses was to use the number of anesthetics administered by clinicians in 2015 to extrapolate the number of anesthetics administered in Ontario over the 20-year period from 1996 to 2015. The final question, regarding number of years in practice since 1996, allowed the number of anesthetics provided by the clinician to be multiplied by the number of years in practice. This allowed for an estimate of the total number of anesthetics administered by each clinician during the 20-year period under investigation. The data from these responses were pooled to estimate the number of anesthetics administered by all clinicians in 2015 and to extrapolate the total number of anesthetics administered in Ontario over the 20-year period from 1996 to 2015. Data collected from study participants were also utilized to extrapolate the numbers of cases administered by survey nonresponders. This was done by taking an average of the responses to estimated number of anesthetics in 2015 and of the number of years in practice for each provider group. This method was based on the estimation protocol described by Estabrooks.[8] In summary, the final estimate of cases over the period from 1996 to 2015 in this study involved the following calculations for each provider group, where A is the estimated average number of anesthetics administered per provider in 20 years and B is the estimated average number of anesthetics administered per nonresponder in 20 years:

$$(\text{Average No. of Years in Practice})(\text{Average No. of Anesthetics Administered per Provider}) = A \quad (1)$$

$$(A)(\text{No. of Nonresponders}) = B \quad (2)$$

In equation 1, the average of the number of years in practice was used to capture any increase or decrease in trends of practice by provider groups. This was to minimize overinflation or underinflation of the final denominator.

The values of B for each provider group were then summed to compute a total number of anesthetics administered by the nonresponders. This total was added to the estimated total anesthetics administered from survey responses to determine the total for the final denominator in this study.

Final values of mortality or morbidity prevalence were therefore represented as:

$$\frac{\text{No. of Events in Mortality OR Morbidity}}{(A+B)} \quad (3)$$

The final mortality and morbidity prevalences were then adjusted to per million cases for ease of comparison to past studies found in literature.

RESULTS

Phase I—Review of Incidents

Because the OCCO database was established in 2002, no records prior to that time (1996–2002) were reviewed. The internal team from the OCCO searched their electronic database from 2002 to 2015, and 42 cases were identified by the search criteria (Figure 1). Forty cases were excluded from the data set, as they did not fit the inclusion criteria. These cases involved death related to oral infection, bacteremia, and airway obstruction due to Ludwig angina, among other causes that were not related to DS/GA. The 2 cases remaining received DS/GA for a dental procedure. Upon review of the case files, 1 case was found to have been performed in a hospital facility. Thus, it did not meet the inclusion criterion of the case

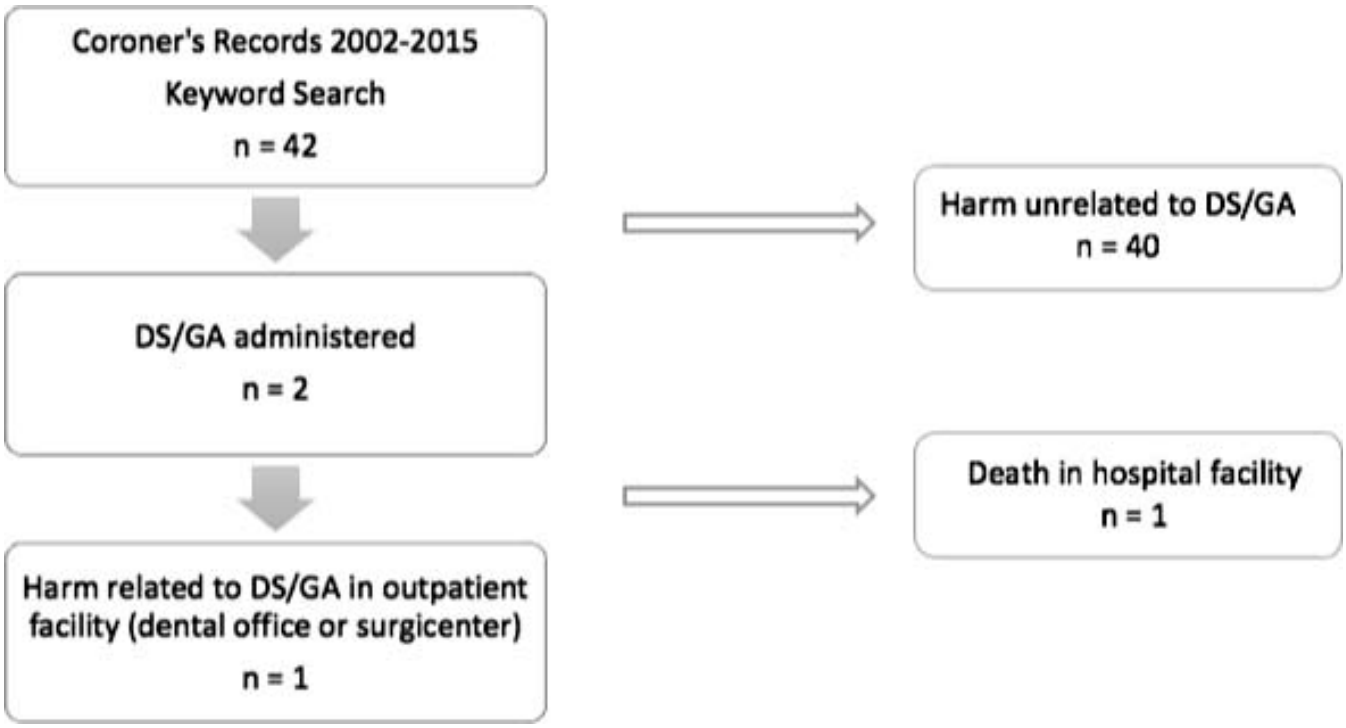

Figure 1. Flow chart for cases forwarded from the Office of the Chief Coroner of Ontario. This diagram shows how cases were excluded from the data set.

occurring in a dental office or surgicenter facility outside of the hospital environment and was therefore excluded. In summary, 1 case was included in the final data set from the original 42 cases forwarded by the OCCO.

In total, 4 cases were forwarded from the RCDSO (Figure 2). The PLP forwarded 2 cases: 1 involved death, and 1 involved serious morbidity. The PCRA also forwarded 2 cases to the investigators. One of these cases occurred under conscious sedation, and therefore

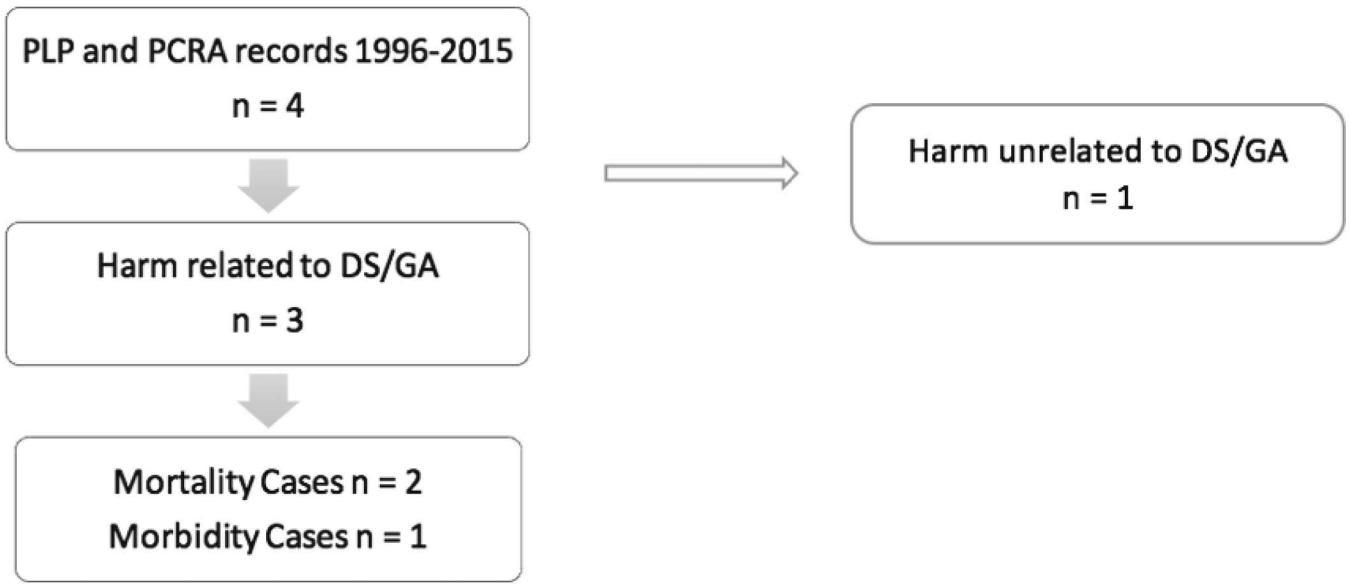

Figure 2. Flow chart for cases forward from the Royal College of Dental Surgeons of Ontario [RCDSO] (Professional Liability Program [PLP] and Professional Conduct and Registry Affairs [PCRA]). This diagram shows how cases were excluded from the data set.

Table 2. Summary of Mortality and Serious Morbidity Cases Included in Data Set*

	PA	*DA*	*OMFS*
Mortality	1	1	1
Severe morbidity	1	0	0
Total	2	1	1

* PA indicates physician anesthesiologist; DA, dentist anesthesiologist; and OMFS, oral maxillofacial surgeon.

did not meet the inclusion criteria for DS/GA. In total, 3 cases were included in the final data set from the RCDSO; 2 involved mortality and 1 serious morbidity.

Based on the combined records from the OCCO and RCDSO, the final data set consisted of 4 patient care events: 3 cases of mortality and 1 case of severe morbidity. Two cases were performed by physician anesthesiologists, 1 case by an oral and maxillofacial surgeon, and 1 by a dentist anesthesiologist (Table 2).

Phase II—Survey of DS/GA Providers

The overall survey response rate was 39.2%, with the highest response rate coming from dentist anesthesiologists (100%), the middle response rate from oral and maxillofacial surgeons (53.4%), and the lowest response rate from physician anesthesiologists (22.9%) (Table 3). The results from survey participants for the year 2015 were multiplied to account for the additional time period from 1996 to 2015 (Table 4). Therefore, the total number of anesthetics administered during the 20-year period from 1996 to 2015 estimated from the survey participant responses was 1,823,822. With respect to the survey nonresponders, survey responder data were extrapolated to account for the number of anesthetics administered by nonresponders. Nonresponders consisted of oral and maxillofacial surgeons and physician anesthesiologists. Based on the average number of anesthetics per provider in each of these responder groups, it was estimated that nonresponders would have administered a total of 1,918,246 anesthetics from 1996 to 2015. The total value calculated for the nonresponders was slightly above the 1,823,822 anesthetics reported by the responding study participants. Together, these 2 values suggest that over the study period, responders and nonresponders administered an estimated total of 3,742,068 anesthetics, or approximately 187,000 anesthetics/y (Table 4).

Table 3. Survey Response Rate*

Provider Group	*Survey Responses, No./Total (%)*
DA	37/37 (100)
OMFS	117/219 (53.4)
PA	75/328 (22.9)
Overall	229/584 (39.2)

* DA indicates dentist anesthesiologist; OMFS, oral maxillofacial surgeon; and PA, physician anesthesiologist.

Table 4. Total Estimated Number of Anesthetics Administered 1996–2015*

Provider Group	*No. of Anesthetics Administered by Survey Responders*	*Estimated No. of Anesthetics Administered by Nonresponders*	*Total*
DA	257,957	0	257,957
OMFS	1,273,643	1,058,046	2,331,689
PA	292,222	860,200	1,152,422
Total	1,823,822	1,918,246	3,742,068

* DA indicates dentist anesthesiologist; OMFS, oral maxillofacial surgeon; and PA, physician anesthesiologist.

The estimated prevalence of mortality in the 20-year period from 1996 to 2015 was thus 3 deaths in 3,742,068 cases, or an adjusted mortality rate of 0.8 deaths per 1 million cases. The estimated prevalence of serious morbidity was 1 injury in 3,742,068 cases, or an adjusted serious morbidity rate of 0.25 per 1 million cases (Table 5). The total prevalence of injury, including both mortality and serious morbidity, yields an adjusted rate of 1.05 events per million cases performed.

DISCUSSION

The mortality rate found in this study was slightly lower than those published by earlier studies conducted in Ontario, and it lies within the range of mortality reported by similar studies for office-based DS/GA in dentistry. Two cases of death were in pediatric patients in the 0–10-year-old group. One case of death and the single case of serious morbidity occurred in adult patients (≥18-year-old group). Because the serious morbidity rate appears to be low, it is arguable that serious injury rarely occurs as a sequela of dentistry under DS/GA.

Previous reports of mortality rates in dental anesthesia have ranged from 1 to as many as 7 deaths per 1 million cases.[4,5,9–13] The mortality rate reported in this study is 0.8 deaths per 1 million cases. This is slightly less than the rate published by Nkansah et al[3] of 1.4 deaths per 1 million cases, and it is the lowest mortality rate published

Table 5. Estimated Mortality and Serious Morbidity Rates

Type of Injury	*Rate*	*Per Million Cases*
Mortality	3 in 3,742,068	0.8
Morbidity	1 in 3,742,068	0.25

to date in the dental anesthesia literature. This lower mortality could be the result of estimation error, or it could be due to increases and improvements in training, monitoring such as the increased use of pulse oximetry and capnography, advances in medications, office anesthesia requirements, or some other factor since the study of Nkansah et al.[3] Importantly, continuous pulse oximetry became part of the RCDSO's guidelines[14] in 1995, and this would likely increase earlier detection of hypoxia and emergencies of a respiratory nature.

It is important to mention that the practice model in Ontario for dental anesthesia involves team based anaesthetic care. The RCDSO 2012 standards of practice for DS/GA describe "the anesthetic team". The anesthetic is administered through the combined efforts of the members of the team which allows a dentist to administer the anesthetic simultaneously with dental treatment.[15] The members include: the dentist-anesthetist (dental anaesthesiologist or oral maxillofacial surgeon), the anesthetic assistant (a registered nurse, respiratory therapist, or an anesthesia assistant), the operative assistant, the recovery supervisor, and the office assistant. The operative assistant role is to keep the operative field free of fluids and foreign objects that may interfere with the patient's airway. The recovery supervisor's role is to monitor the patient through recovery and discharge; they are under the dentist's supervision. The office assistant functions to attend to the logistics of the office so that the anesthetic team is not disturbed. However, if a dental anesthesiologist or physician anesthesiologist is solely administering the anaesthetic, then an anaesthetic assistant or recovery supervisor are not required as members of the team.[15] This model not only ensures that the members of the team administering the anaesthetic are not distracted from monitoring the patient, but it also means there are several trained individuals attending to the patient's well-being.

Somri et al[16] hypothesized that the decrease in claims related to anesthesia from 1975 to 2000 was due to improved training, the use of safer drugs, and increased focus on patient safety. Indeed, the duration of training for dentist anesthesiologists in Ontario has increased with time. Founded in 1960, the dental anesthesia specialty program at the University of Toronto was originally 12 months in duration, and it is now 36 months in duration, the majority of which is dedicated to clinical anesthesia training. All dental anesthesiology training programs in the United States have also transitioned to 36 months' duration. Commission on Dental Accreditation requirements for these programs have defined competencies for all aspects of managing patients under sedation and GA for dental procedures. The increasing popularity and use of simulation as an educational tool during training also has known benefits leading to a potential safety advantage.[17] The regulatory landscape in Ontario has also evolved from providing guidelines for management[13] in 1995 to clearly defining enforceable standards of care.[15] Globally, recognition of human error in patient safety[18,19] and an awareness of the ambulatory environment and its unique challenges compared to hospital-based practice[20] may also represent changes in health care that contribute to more careful practice and ultimately lowered mortality. Although monitoring, training, and standards have improved, these improvements have largely been recent changes. It is unknown what relative contribution these have made to our results, as these changes may be more evident in future studies.

There are limitations to our study. The study design was retrospective. For collection of morbidity and mortality data, a prospective design is ideal. However, because the reported prevalence of morbidity and mortality in DS/GA for dentistry is low, a prospective study would have to be conducted over a very long period to accurately estimate the prevalence of morbidity and mortality.[21] Our study design is a reasonable alternative given that no prospective database is in use in Ontario at the time of this study.

Phase I findings of mortality and morbidity were based on case reports and identified through the cooperation of 2 organizations, the RCDSO and the OCCO. Although the search methods employed have limitations, at the time of this study, they were the only avenue of access to these cases in Ontario. A key strength of this study was the approach to collect data from 3 different sources from 2 independent organizations: the OCCO and the PLP and PCRA of the RCDSO. Past dental anesthesia morbidity and mortality studies have relied on personal report from clinicians of adverse events,[4,5,10,12,13] and our study represents a potential improvement in these methods, as it avoids self-report, recall, and social desirability bias. However, in phase I of the results, it should be noted that there was no overlap between cases forwarded from the RCDSO and OCCO. There was a case of mortality that came up in the RCDSO's records that was not included in the OCCO records and vice versa. The lack of overlap highlights that the search method used by the internal teams may not have been comprehensive despite best efforts, and because of errors by the individuals screening cases. This emphasizes the difficulty of accessing information without a database designed specifically to capture these data prospectively.

Phase II findings were based on the responses to the mail-based survey. The number of anesthetics administered in the above-mentioned period was estimated with a survey tool and extrapolation based on survey responses. Clinicians were specifically asked, "In the

12-month period from January 1, 2015–December 31, 2015, how many deep sedations/general anesthetics did you administer?" This question was worded to ensure that clinicians would not include conscious or moderate sedation cases in their estimate. Additionally, it is unlikely that mild or moderate sedations were included in survey responses, as only providers of DS and GA were included as participants in the survey.

The overall survey response rate of 39.2% was within the range of reported response rates of Canadian dentists and physicians. For example, surveys of Canadian dentists have reported response rates ranging from 17 to 38%.[22–24] Surveys of Canadian physicians appear to be higher in the range of 54–66%.[25,26] The response rate for dentist anesthesiologists was 100%, which allowed us to compute a reasonable estimate of the number of anesthetics this provider group may have administered during the study period. The response rates for oral and maxillofacial surgeons (53.4%) and physician anesthesiologists (23%) mean that the estimates of the number of DS/GA cases may not be entirely accurate. A similar limitation is that the data collected from responders were averaged and extrapolated to estimate the anesthetics performed by the nonresponders to the survey. Because the response rate in the physician anesthesiologist group was lowest at 23%, the data collected from this provider group could have been the least accurate. Again, this would result in possible overestimation or underestimation of the final number of anesthetics administered by this group once the data were extrapolated for nonresponders. The way in which survey questions were formulated may also have had an impact on the nature of the data reported. Clinicians indicated how many years they had been in practice since 1996. The response to this question was used as the multiplier to extrapolate the number of anesthetics each clinician administered in the 20-year period, based on their reported number of DS/GA services provided in the calendar year 2015. Although this assumes a steady state over time, it is unlikely clinicians performed the same number of anesthetics each year they were in practice as they did in the calendar year 2015. Variability in the number of anesthetics over time was not, therefore, captured in the calculation. However, asking the question of the number of years in practice helped to ensure that data from clinicians who had been in practice for a shorter period would not overinflate the total number of anesthetics administered. Based on these limitations and the extrapolation of responses, the total number of anesthetics should be interpreted with caution.

Our research found 2 pediatric deaths, 1 adult death, and 1 adult case of serious morbidity related to DS/GA for dentistry in Ontario from 1996 to 2015, with a corresponding mortality rate of 0.8 deaths per 1 million cases and morbidity rate of 0.25 serious morbidity events per 1 million cases—a total of 1.05 serious injury events per million cases. This arguably represents a low rate and is reflected by Calman and Royston's[27] verbal scale as a "negligible" risk. The logarithmic community cluster classification based on Calman and Royston's[27] verbal scale has been employed by several authors to describe the risk of adverse events in anesthesia in patient-centered and relatable terms.[27] Jenkins and Baker[28] summarized studies reporting predicted incidences of complications of anesthesia in relation to Calman and Royston's[27] verbal scale to lend perspective on the risk. We have added published dental anesthesia mortality and morbidity rates to their graphical representation to illustrate where the predicted mortality and morbidity rates related to dentistry under DS/GA lie (Table 6). Although both the mortality and morbidity rates would correspond with a "negligible" risk, given the limitations in retrospective data collection, the mortality rate may be more confidently associated with a "minimal" risk as reflected by Calman and Royston's[27] verbal scale (Table 6).

Because death due to anesthesia in dentistry is a rare event, the estimation of the risk of mortality associated with anesthesia is most accurate when the number of actual anesthetics provided is very large.[21] This study was therefore underpowered for subgroup analyses by provider group. However, as the dentist anesthesiologist group had a 100% response rate, we considered an estimate of mortality intriguing and a subgroup analysis was performed despite insufficient data. The estimated total number of anesthetics for the 20-year period from 1996 to 2015 based on the report of 37 providers was 257,957. There was 1 death in this group. Therefore, the mortality rate for dentist anesthesiologist providers during this time period using these underpowered data was 3.9 per 1 million DS/GAs, or 1 case per 256,410 DS/GAs. There were no serious morbidities. Although this rate is higher than the overall mortality rate found in this study, it still corresponds with a "minimal" risk as reflected by Calman and Royston's[27] verbal scale (Table 6).

A comparison of our prevalence rate with the prevalence rate reported in the most recently published study reviewing mortality and morbidity for dental anesthetics[9] provides some additional perspective. In the 14-year period from 2000 to 2013, a somewhat similar time period to our study, the Oral and Maxillofacial Surgery National Insurance Company, which insures approximately 80% of oral and maxillofacial surgeons in the United States, conducted a retrospective review of mortality and morbidity. They estimated Oral and Maxillofacial Surgery National Insurance Company–insured practitioners administered 39,392,008 office-

Table 6. Modified Community Cluster Logarithmic Scale of Risk Classification Identifying Medical and Dental Anesthesia Examples*

Risk Level	*Calman and Royston's[26] Verbal Scale*	*Community*	*Community Examples*	*Medical Anesthesia Examples†*	*Reported Dental Anesthesia Rates*
1:1–9	Very high	Sibling	Genetic dominant	Postoperative nausea and vomiting 1:4 Dizziness 1:5 Headache 1:5	
1:10–99	High	Family	Genetic recessive	Oral trauma 1:20 Emergency surgery death 1:40 Difficult intubation 1:50	
1:100–999	Moderate	Street	Death of any cause (1:100)	Perioperative death 1:200 Awareness without pain 1:300 Failure to intubate 1:500	
1:1000–9999	Low	Village	Traffic deaths/y (1:8000)	Aspiration 1:3000 Cardiac arrest (local anesthesia) 1:3000 Failure to intubate and ventilate 1:5000	
1:10,000–99,999	Very low	Small town	Accidental deaths at home/y (1:11,000)	Anaphylaxis 1:10,000 Cardiac arrest (GA) ~1:15,000 Death related to anesthesia 1:50,000	Serious morbidity reported by D'Eramo[3] 1:37,400
1:100,000–999,999	Minimal	Large town	Rail accidents/y (1:140,000)	Loss of vision (GA) 1:125,000 Death due solely to anesthesia 1:180,000	Serious morbidity reported by Deegan[11] 1:364,280 Mortality reported by Bennett et al[9] 1:344,828 Nkansah et al[3] 1:714,285 This study (mortality) 1:1,250,000
1:1,000,000–9,999,999	Negligible	City	6 balls in UK National Lottery (1:2,796,763)		This study (morbidity) 1:3,742,068
1:10,000,000–99,999,999	Minute	Country	Lightning deaths/y (1:10,000,000)		

* GA indicates general anesthesia.
† From Jenkins and Baker.[27]

based anesthetics,[9] with 71% of these being GAs and the remaining 29% termed "sedation anesthetics."[8] Although there was no clear definition of the term sedation anesthetics, it is likely that this term described cases where a level of sedation below GA was administered. During this time period, there were 113 cases that resulted in patient death or brain injury. This yielded a prevalence of 1 patient death or brain injury every 348,602 anesthetic procedures, which was estimated to be 1 injury event occurring every 6.4 weeks.[9] Additionally, there were 3 cases of stroke that occurred.[8] This would result in a total injury prevalence rate (combined mortality and morbidity) of 116 cases per 39,392,008, corresponding to ~3 serious injury events per 1 million cases. Although their study did not explicitly restrict the data set to exclusively DS/GA, this type of sedation was the majority of the data set (79%). Had their data set been restricted to only DS/GAs, it is possible their serious injury rate could be higher than published. DS/GA carries greater risk compared to other levels of sedation, and the inclusion of other types of sedation in the total case count (denominator) may have diluted the impact of serious injury events (numerator), reducing the overall prevalence rate of serious injury with relation to DS/GA. Our current study reports rates consistent with the recent study by Bennett et al[9]; both have identified serious injury prevalence rates within the lower range reported in the dental anesthesia literature, which vary from 0 to 7 deaths per 1 million cases.

This study adds to our knowledge regarding the potential risks of DS/GA in the dental office setting. Its importance is based on the understanding that DS/GA is

indicated for many patients and represents a necessary service. Thus, there are several implications of these results. For patients, this information of the estimated mortality and morbidity for those undergoing DS/GA care for dentistry in Ontario can be used to enhance informed consent for these procedures. This study also indicates the need for a reliable surveillance system to be established to accurately monitor mortality and morbidity events. This is essential to facilitate access of the professional community for incident review to reduce the likelihood of similar events occurring. Without this, the benefit of incident reporting is minimized. Acknowledging that the provision of anesthesia has inherent risk, the results of this study should provide further evidence for the overall relative safety of DS/GA for dental procedures in the office- and surgicenter-based environment in Ontario.

CONCLUSION

This study investigated the prevalence of mortality and serious morbidity events for dental procedures under DS/GA performed outside of a hospital facility from 1996 to 2015. The mortality rate was found to be 0.8 deaths per 1 million cases, and the serious morbidity rate was found to be 0.25 per 1 million cases, for a total prevalence of 1.05 serious injury events in 3,742,068 DS/GA cases. The prevalence of mortality for dentistry under DS/GA in Ontario found was comparable to the rate previously reported by Nkansah et al.[2] The range of mortality rates reported in the dental anesthesia literature range from 0 to 7 deaths per 1 million cases.[3–5,9,10–13] The rate found in this study fits within the lower end of this range. The serious morbidity rate was found to be low, indicating that serious injury rarely occurs as a sequela of dentistry under DS/GA.

Future research in this area could focus on the establishment of a surveillance system and piloting different techniques. It could also explore the prevalence of mortality and morbidity events for dentistry under DS/GA in Canada and North America overall. DS and GA are valuable services for those who cannot receive dental treatment in a conventional manner, and it is our duty to ensure that patient safety remains the most important aspect of this procedure.

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