Clinical Oral Investigations (2023) 27:5475–5483
https://doi.org/10.1007/s00784-023-05166-0

RESEARCH

A survey on the safety of anesthesia management provided by dental anesthesiologists in Japan: a 5-year survey by the Japanese Dental Society of Anesthesiology

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Received: 28 June 2022 / Accepted: 13 July 2023 / Published online: 17 July 2023

Abstract

Objectives The Japanese Dental Society of Anesthesiology (JDSA) has conducted a survey on the safety of anesthetic practice provided by dental anesthesiologists. This report includes information on the incidence of life-threating events, which is necessary for evaluating the safety of dental anesthesia.

Material and methods This study was designed as a retrospective observational questionnaire-based survey. All 32 JDSA accredited training facilities participated in this study. The accredited facilities were requested to provide annual data on basic demographic information concerning anesthetic management during the 5-year period from 2014 to 2018, inclusive. Details regarding life-threatening events were also requested.

Results During the survey period between 2014 and 2018, a total of 219,343 cases of anesthetic management (80,138 cases of general anesthesia, 127,819 cases of sedation, and 11,386 cases of monitoring) were reported by the 32 JDSA accredited training facilities. The overall incidence of life-threatening events occurring during clinical dental anesthesia was 2.14/10,000, while the incidence of anesthesia-related events was 0.96/10,000. No deaths arising from anesthesia-related events occurred.

Conclusions This is the first survey on clinical outcomes of dental anesthesia to be conducted. The survey results provide evidence supporting the safety of anesthetic management as performed by dental anesthesiologists.

Clinical relevance The results of this study will provide a basis for benchmarking the safety of dental anesthesia not only in Japan, but also around the world.

Keywords Cardiac arrest · Dental anesthesia · General anesthesia · Life-threatening events · Sedation

Introduction

Dr. Horace Wells, a dentist in Hartford, Connecticut, was the first to apply nitrous oxide to clinical anesthesia in 1844 [1–3]. In 1846, Dr. William Morton, a dentist in Boston, Massachusetts, succeeded in the public demonstration of general anesthesia using ether as an inhalation anesthetic for the first time [1–3]. The pioneering work of these two dentists was a great aid to the advancement of modern anesthesiology. Furthermore, their efforts provide historical proof that dentistry has fought against pain and anxiety for well over a century.

An annual report provided by the Japanese Ministry of Health, Labour and Welfare (JMHLW) in 2018 indicated that 84,349 cases of general anesthesia and 88,733 cases of intravenous sedation are performed annually in the field of dentistry, for a total of approximately 170,000 cases requiring anesthesia care each year.

The Japanese Dental Society of Anesthesiology (JDSA) was established in 1973 to develop dental anesthesiology in Japan [4]. Dental anesthesiology is positioned as an independent field in dentistry, specializing in the management of anxiety and pain and the provision of safety controls.

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The JDSA has grown to become a professional and academic association with 2,796 members (including 1,334 members of the Japanese Boards of Dental Anesthesiologists [JBDA] and 338 Board-Certified Dental Anesthesiology Specialists [BCDAS]) as of February 14, 2022. However, the safety and outcomes of anesthetic management performed by dental anesthesiologists in Japan has not been explored. The objective of this survey was to investigate the safety of anesthetic management performed by dental anesthesiologists at 32 JDSA-certified training facilities during a survey period from 2014 to 2018.

Methods

In Japan, dentists are legally allowed to perform general anesthesia and sedation as long as the target disease is in the field of dentistry. However, anesthesia care for oral surgery and dental treatment are generally performed by dental anesthesiologists, not general dentists. Most dental anesthesiologists in Japan work at JDSA-accredited training facilities; in recent years, however, an increasing number have begun working at general hospitals, community clinics, or private dental offices. There are 32 JDSA-certified training facilities in Japan. The JDSA training facilities consist of 30 dental school-related hospitals, one dental hospital, and one dental clinic. All facilities provide a JDSA-qualified curriculum for training dental anesthesiologists. These facilities also contribute to the education of dental students in dental schools, as well as educational programs in local communities.

All 32 JDSA-accredited training facilities participated in this study. After approval from the ethics committee of the JDSA (approval numbers: 1920-3 and 1920-4), the survey was also approved by the individual ethics committees of each accredited facility.

This study was designed as a retrospective observational questionnaire-based survey covering a 5-year period from 2014 to 2018, inclusive. The survey questionnaire was created based on an existing survey on anesthesia-related events created by the Japanese Society of Anesthesiologists (JSA) [5]. The accredited facilities were given a spreadsheet template and asked to provide annual case numbers for the following anesthetic management items: basic demographic information (sex, American Society of Anesthesiologists physical status [ASA PS], age group), body position during procedure, type of anesthesia (general anesthesia, sedation, or vital sign monitoring). Vital sign monitoring is a clinical practice without anesthetics intervention that is performed to secure the safety of patients during dental treatment. Medically compromised patients are prone to sudden deteriorations in their cardiovascular conditions; thus, vital sign monitoring is required to secure the safety of patients during dental procedures.

The following information concerning life-threatening events was requested: 1) type of event (cardiac arrest, severe hypotension, severe hypoxia, life-threatening arrythmia and others), 2) time when the event occurred, 3) possibility of prevention, 4) outcome at 30 days after the accidental event, 5) primary cause of the event, and 6) origin of the event (only for events associated with anesthetic management) [5]. A life-threatening event was defined as 1) an event for which a dental anesthesiologist considered any intervention was required to prevent cardiac arrest or serious subsequent complications, such as cardiac damage or impaired consciousness, and 2) hypotension, hypoxia or arrythmia suggesting impending systemic failure. Other life-threatening events were defined as events that could not be classified as cardiac arrest, severe hypotension, severe hypoxia, or life-threatening arrythmia. For the collection of data on life-threatening events, drop-down lists were added to the spreadsheets to reduce any reporting bias caused by open-ended questions. Deaths occurring 30 days after a life-threatening event were identified from the anesthesia registry at each facility.

The spreadsheet template was distributed from the JDSA office to the 32 JDSA-accredited facilities on March 17, 2021, and the accredited facilities were required to electronically send the completed questionnaire back to the JDSA office by June 30, 2021. All data registered in the template were not linked with the patients' personal information and were anonymized at each facility. Moreover, the data was not linked between items. The names of the individual facilities were blinded for the analysis. All collected questionnaires were sent to the members of the Database Construction Working Group of the JDSA. The working group checked the individual data to ensure the completeness of the survey. Any input errors, such as a mistype or blank field, were corrected to ensure the survey's reliability. Requests for data correction were sent to the accredited facilities through the JDSA office.

Results

All 32 JDSA accredited training facilities electronically submitted the completed questionnaires to the JDSA office by the designated deadline. Ambiguous information provided by any facility was repeatedly confirmed and corrected through the JDSA office to ensure the reliability of the data. All the data entries were analyzed in a blinded manner with regard to their origins.

Number of anesthetic management cases during the 5-year period

During the survey period between 2014 and 2018, a total of 219,343 cases of anesthetic management (80,138 cases of

general anesthesia, 127,819 cases of sedation, and 11,386 cases of monitoring) were reported by the 32 JDSA accredited training facilities (Table 1). The number of cases of anesthetic management increased moderately from 41,645 in 2014 to 46,495 in 2018. Roughly 1,200 cases of anesthetic management were conducted at a single facility annually.

Basic demographic information regarding the anesthetic management cases

The basic demographic information for the patients is presented in Table 2. The cohort consisted of 100,297 men (45.7%) and 119,046 women (54.3%). Most of the patients had a good general condition, with 56.8% (124,502 cases) having an ASA PS of 1 and 41.3% (90,501 cases) having an ASA PS of 2. Forty-three cases had an ASA PS of 4, and 3 cases had an ASA PS of 5. Emergency treatments accounted for less than 0.5% of the total anesthetic management cases. Infants (less than 1 year old) accounted for 1,353 cases (0.612%), and seniors (85 years or older) accounted for 2,526 cases (1.2%). Most cases (219,111 [99.9%]) were treated in the supine position.

Incidence of life-threatening events during the 5-year period

A total of 47 life-threatening events occurred among the 219,343 cases in this cohort (2.14/10,000) (Table 3). Forty-three life-threatening events occurred in the general anesthesia group, while 4 events occurred in the sedation group; no events were reported in the vital sign monitoring group. The incidences of life-threatening events and deaths within 30 days after the events were 2.14/10,000 (47/219,343 cases) and 0.05/10,000 (1/219,343 cases), respectively. Among the patients who developed life-threatening events, the mortality rate was 2.1% (1/47 cases). The cause of the single death was cardiac arrest during the induction of general anesthesia in a patient with pre-existing severe cardiovascular disease. Since the data was collected under the precondition that detailed reports were unnecessary, further details of this case are unknown. However, the report stated that the death was not related to anesthesia. The incidences of anesthesia-related life-threatening events and deaths within 30 days after the events were 0.96/10,000 (21/219,343 cases) and 0/10,000 (0/219,343 cases) among the anesthetic management cases.

Cardiac arrest

The incidences of all cardiac arrest events and deaths within 30 days after the events were 0.18/10,000 and 0.05/10,000 cases, respectively; the mortality rate of patients who developed cardiac arrest was 25.0%. Among these cases, the incidences of anesthesia-related cardiac arrest events and deaths within 30 days after the events were 0.05/10,000 and 0/10,000 cases, respectively.

Severe hypotension

The incidence of severe hypotension events was 0.41/10,000 cases. Among these cases, the incidence of anesthesia-related severe hypotension events was 0.14/10,000 cases.

Severe hypoxia

The incidence of severe hypoxia events was 0.59/10,000 cases. Among these cases, the incidence of anesthesia-related severe hypoxia events was 0.41/10,000 cases.

Life-threatening arrhythmia

The incidence of life-threatening arrhythmia events was 0.18/10,000 cases. Among these cases, the incidence of anesthesia-related life-threatening arrhythmia events was 0/10,000 cases.

Table 1 Anesthetic management cohort during a 5-year period

Year		2014	2015	2016	2017	2018	Total
Overall cases	Number	41,645	42,908	43,883	44,412	46,495	219,343
	Number per facility, Mean [SD]	1,301 [892]	1,341 [850]	1,371 [915]	1,388 [940]	1,453 [1,088]	
General Anesthesia	Number	15,408	15,709	15,689	16,567	16,765	80,138
	Number per facility, Mean [SD]	482 [224]	491 [233]	490 [251]	518 [248]	524 [266]	
Sedation	Number	24,483	24,858	25,714	25,464	27,300	127,819
	Number per facility, Mean [SD]	765 [714]	777 [681]	804 [741]	796 [746]	853 [909]	
Vital sign monitoring	Number	1,754	2,341	2,480	2,381	2,430	11,386
	Number per facility, Mean [SD]	55 [120]	73 [151]	78 [151]	74 [155]	76 [149]	

SD, standard deviation

Table 2 Cohort Background

		Overall cases		General anesthesia		Sedation		Vital sign monitoring	
		n = 219,343		*n* = 80,138		*n* = 127,819		*n* = 11,386	
		n	%	n	%	n	%	n	%
Sex	Male	100,297	45.7	40,688	50.8	53,988	42.2	5,621	49.4
	Female	119,046	54.3	39,450	49.2	73,831	57.8	5,765	50.6
ASA PS	I	124,502	56.8	47,915	59.8	73,944	57.9	2,643	23.2
	II	90,501	41.3	30,867	38.5	52,086	40.7	7,548	66.3
	III	3,762	1.7	973	1.2	1,660	1.3	1,129	9.9
	IV	43	0.02	7	0.01	7	0.01	29	0.3
	V	3	0.001	0	0	0	0	3	0.03
	I, E	240	0.1	165	0.2	62	0.05	13	0.1
	II, E	244	0.1	180	0.2	50	0.04	14	0.1
	III, E	47	0.02	31	0.04	10	0.01	6	0.1
	IV, E	1	0.0005	0	0	0	0	1	0.01
	V, E	0	0	0	0	0	0	0	0
Age group	< 4 w	13	0.01	10	0.01	1	0.001	2	0.02
	4 w to < 1 y	1,340	0.611	1,291	1.6	0	0	49	0.4
	1 y to < 6 y	6,335	2.9	5,320	6.6	901	0.7	114	1.0
	6 y to < 19 y	23,696	10.8	16,007	20.0	7,117	5.6	572	5.0
	19 y to < 66 y	156,254	71.2	47,600	59.4	101,887	79.7	6,767	59.4
	66 y to < 86 y	29,179	13.3	9,285	11.6	16,489	12.9	3,405	29.9
	≥ 86 y	2,526	1.2	625	0.8	1,424	1.1	477	4.2
Body position	Supine	219,111	99.9	80,016	99.8	127,790	99.98	11,305	99.3
	Prone	21	0.01	21	0.03	0	0	0	0
	Lateral	119	0.05	101	0.1	8	0.01	10	0.1
	Sitting	92	0.04	0	0.0	21	0.02	71	0.6
Type of procedure	Oral and maxillofacial surgery	135,884	61.95	70,681	88.20	59,310	46.4	5,893	51.76
	Dental treatment	82,031	37.40	9,438	11.78	67,224	52.6	5,369	47.15
	Examination	184	0.08	9	0.01	130	0.1	45	0.40
	Others	1,244	0.57	10	0.01	1,155	0.9	79	0.69

ASA PS, the American Society of Anesthesiologists physical status; *PS* I, a normal healthy patient; *PS* II, a patient with mild systemic disease; *PS* III, a patient with severe systemic disease; *PS* IV, a patient with severe systemic disease that is a constant threat to life; *PS* V, a moribund patient who is not expected to survive without the operation; E, emergency surgery. Examination, diagnostic imaging (X-rays, computed tomography scans, and magnetic resonance imaging scans)

Other life-threatening events

The incidence of other life-threatening events was 0.78/10,000 cases. Among these cases, the incidence of anesthesia-related other life-threatening events was 0.36/10,000 cases.

Analysis of anesthesia-related life-threatening events

Among the 21 anesthesia-related life-threatening events that were reported, 12 (57.1%) out of 21 anesthesia-related life-threatening events were attributed to human errors (Table 4a): 41.7% (5/12) were drug-related, and 33.3% (4/12) were related to respiration management (Table 4b).

Discussion

This is the first survey of the safety of dental anesthesia to be conducted in Japan. The overall incidence of life-threatening events occurring during clinical dental anesthesia was 2.14/10,000, while the incidence of anesthesia-related events was 0.96/10,000. No deaths caused by anesthesia-related events occurred during the 5-year period between 2014 and 2018, inclusive.

Table 3 Incidence of life-threatening events during a 5-year period

		Anesthetic management	General anesthesia	Sedation
Overall life-threatening events	Overall life-threatening events	47	43	4
	Incidence (/10,000 cases)	2.14	5.37	0.31
	Deaths within 30 days after events	1	1	0
	Incidence (/10,000 cases)	0.05	0.12	0
	Mortality rate after events	2.1%	2.3%	0%
	Anesthesia-related life-threating events	21	19	2
	Incidence (/10,000 cases)	0.96	2.37	0
	Deaths within 30 days after anesthesia-related events	0	0	0
	Incidence (/10,000 cases)	0	0	0
	Mortality rate after anesthesia-related events	0%	0%	0%
Cardiac arrest	Overall cardiac arrest	4	3	1
	Incidence (/10,000 cases)	0.18	0.37	0.08
	Deaths within 30 days after cardiac arrest	1	1	0
	Incidence (/10,000 cases)	0.05	0.12	0
	Mortality rate after cardiac arrest	25.0%	33.3%	0%
	Anesthesia-related cardiac arrest	1	1	0
	Incidence (/10,000 cases)	0.05	0.12	0
	Deaths within 30 days after anesthesia-related cardiac arrest	0	0	0
	Incidence (/10,000 cases)	0	0	0
	Mortality rate after anesthesia-related cardiac arrest	0%	0%	0%
Severe hypotension	Overall severe hypotension	9	8	1
	Incidence (/10,000 cases)	0.41	1.00	0.08
	Deaths within 30 days after severe hypotension	0	0	0
	Incidence (/10,000 cases)	0	0	0
	Mortality rate after severe hypotension	0%	0%	0%
	Anesthesia-related severe hypotension	3	2	1
	Incidence (/10,000 cases)	0.14	0.25	0.08
	Deaths within 30 days after anesthesia-related severe hypotension	0	0	0
	Incidence (/10,000 cases)	0	0	0
	Mortality rate after anesthesia-related severe hypotension	0%	0%	0%
Severe hypoxia	Overall severe hypoxia	13	11	2
	Incidence (/10,000 cases)	0.59	1.37	0.16
	Deaths within 30 days after severe hypoxia	0	0	0
	Incidence (/10,000 cases)	0	0	0
	Mortality rate after severe hypoxia	0%	0%	0%
	Anesthesia-related severe hypoxia	9	8	1
	Incidence (/10,000 cases)	0.41	1.00	0.08
	Deaths within 30 days after anesthesia-related severe hypoxia	0	0	0
	Incidence (/10,000 cases)	0	0	0
	Mortality rate after anesthesia-related severe hypoxia	0%	0%	0%

Table 3 (continued)

		Anesthetic management	General anesthesia	Sedation
Life-threatening arrhythmia	Overall life-threatening arrhythmia	4	4	0
	Incidence (/10,000 cases)	0.18	0.50	0
	Deaths within 30 days after life-threatening arrhythmia	0	0	0
	Incidence (/10,000 cases)	0	0	0
	Mortality rate after life-threatening arrhythmia	0	0	0
	Anesthesia-related life-threatening arrhythmia	0	0	0
	Incidence (/10,000 cases)	0	0	0
	Deaths within 30 days after anesthesia-related life-threatening arrhythmia	0	0	0
	Incidence (/10,000 cases)	0	0	0
	Mortality rate after anesthesia-related life-threatening arrhythmia	0	0	0
Others	Overall severe accidental events	17	17	0
	Incidence (/10,000 cases)	0.78	2.12	0
	Deaths within 30 days after severe accidental events	0	0	0
	Incidence (/10,000 cases)	0	0	0
	Mortality rate after severe accidental events	0	0	0
	Anesthesia-related severe accidental events	8	8	0
	Incidence (/10,000 cases)	0.36	1.00	0
	Deaths within 30 days after anesthesia-related severe accidental events	0	0	0
	Incidence (/10,000 cases)	0	0	0
	Mortality rate after anesthesia-related severe accidental events	0	0	0

Table 4 Factorial analysis of anesthesia-related life-threatening events

a. Analysis of 21 anesthesia-related serious events		
Cause	n	%
Human factor	12	57.1
Details unknown	9	42.9
Timing	n	%
Preoperative	10	47.6
Intraoperative	4	19.0
Postoperative	7	33.3
b. Details of 12 cases categorized as anesthesia-related life-threatening events involving a human factor		
Details	n	%
Overdose or wrong drug	3	25.0
Overdose of main anesthesia agent	2	16.7
Inappropriate airway management at anesthesia induction	2	16.7
Inappropriate ventilation	1	8.3
Aspiration	1	8.3
Details unknown	3	25.0
Timing	n	%
Preoperative	4	33.3
Intraoperative	3	25.0
Postoperative	5	41.7

One of the most important missions of the JDSA is to contribute to the improvement of the safety of dental care and clinical dental anesthesia. For this mission, the JDSA is engaged in the following projects: 1) implementation of research and investigation concerning safety in dental treatment or dental anesthesia, 2) various clinical qualification projects (Japanese Board of Dental Anesthesiologist [JBDA] and Board-Certified Dental Anesthesiology Specialist [BCDAS]), 3) hosting of academic conferences, lecture meetings and education training workshops, and 4) establishing various guidelines for dental treatment or dental anesthesia. JDSA-accredited training facilities are recognized by the JDSA as having a sufficient number of cases and available equipment necessary to teach the clinical skills and knowledge required for the practice of dental anesthesiology. All cases treated at the JDSA-accredited training facilities were managed under the supervision of the directors of those facilities; the directors of the facilities had completed the BCDAS or JBDA qualifications.

JDSA-certified dentist members obtain two certifications: first the JBDA, and then the BCDAS. JBDA is the first stage of qualification, requiring 3 years of training and a primary board examination. BCDAS is the second, more advanced, stage of qualification, requiring 5 years of training and an

advanced board examination. The primary role of the JBDA is to contribute to the improvement of safety in the dental care community. The roles of the BCDAS, on the other hand, are to improve safety, to provide guidance to prospective dental anesthesiologists, and to promote dental anesthesiology within the medical community. The BCDAS System was officially approved by the JMHLW of Japan in 2006. BCDAS qualification requires more than five consecutive years of full-time postdoctoral training at JDSA accredited training facilities, during which applicants shall have managed more than 500 dental anesthesia cases. Thus, our certification system for anesthesia management is thought to contribute to the safety of dental anesthesia in Japan.

This study found that approximately 16,000 cases of general anesthesia and 25,000 cases of sedation were performed at the 32 JDSA-accredited training facilities annually. Although these numbers included both in-medical insurance system and out-of-medical insurance system cases, most of the cases were considered to be in-medical insurance system cases. As mentioned above, an annual report provided by the JMHLW in 2018 indicated that 84,349 cases of general anesthesia and 88,733 cases of intravenous sedation in dentistry were performed annually in Japan (Accessed May 30, 2023: https://www.mhlw.go.jp/content/12400000/000539783.xlsx, in *Japanese*). These numbers reported by the JMHLW included only in-medical insurance system cases. Consequently, more than 80% of general anesthesia cases (at a minimum) and 70% of intravenous sedation in dentistry cases were performed at institutions other than JDSA-accredited training facilities.

The incidence of cardiac arrest, including anesthesia-related cardiac arrest, can be used as an index for comparing the safety of anesthetic management among countries or health care providers. The JSA has investigated the incidence of life-threatening events during anesthesia since 1992 [5]. The JSA survey is one of the largest, the oldest, and the most organized surveys on the safety of anesthesia in the world (2,125,640 anesthesia cases at 1086 facilities in 2016). The JSA survey has shown that the incidence of life-threatening events has been declining since the study began [5]. In the latest JSA survey, the incidences of cardiac arrest and anesthesia-related cardiac arrest in 2016 were 2.3/10,000 and 0.96/10,000, respectively [5]. A teaching hospital in China investigated 152,513 anesthesia cases over 10 years (2007–2017) [6]. They reported that 104 cases (6.8/10,000) developed cardiac arrest and that 11 cardiac arrest cases (0.7 /10,000) were attributed to anesthesia [6]. In a single-center study performed in Portugal, which examined 122,289 anesthesia cases over approximately 7 years (2008–2015), the incidences of cardiac arrest and anesthesia-related cardiac arrest were reported to be 5.07/10,000 and 0.74/10,000, respectively [7]. These data can be used as a reference for comparison with our results; however, the data cannot be directly compared with our data because the backgrounds of the enrolled cases differ and these differences are very likely to affect the reported incidences. Nunnally et al. reported that the incidences of cardiac arrest are trending higher in patients aged < 1 year and > 80 years and in patients with an ASA PS of IV or V [8]. In the presently reported cohort, the patient backgrounds included more than 98% with an ASA PS of I or II and an age of > 1 year and < 86 years (Table 2). Moreover, the percentage of sedation in overall anesthetic management was dominant (127,819/219,343 cases [58.3%]). Further consideration of methods to reduce biases arising from patient backgrounds is needed to compare the present data with that available from other studies. Considering these background differences, our data demonstrating a cardiac arrest incidence of 0.18/10,000 cases and an anesthesia-related cardiac arrest incidence of 0/10,000 seem to confirm the safety of dental anesthesia in Japan. In this 5-year survey, only one death occurred in a patient receiving general anesthesia; the death was reported as having been caused by pre-existing severe cardiovascular disease. Our cohort included 43 cases with an ASA PS of IV and 3 cases with a PS of V. Thus, anesthesia care was provided even for critically ill patients. For example, tooth extraction to prevent sepsis or drainage of the maxillo-facial region to secure airway patency might be performed as a life-saving procedure, even in high-risk patients. Therefore, high-risk cases are possible even in dental anesthesia, and dental anesthesiologists must have experience managing high-risk patients. In this 5-year survey, the 3 cases with a PS of 5 were the same patient. This patient required dental treatment under vital sign monitoring on three occasions: once each in 2015, 2016, and 2017. The patient had Down syndrome and severe heart disease (complicated by Eisenmenger syndrome and severe pulmonary hypertension); he died of heart failure in 2017.

No other organized society in the world has published statistics on the safety of dental anesthesia. The United States has a much larger number of dental anesthesia cases than Japan, with case numbers per population of approximately ten times the number in Japan. Although official data on the safety of dental anesthesia is not available, the closed claims database of the Oral and Maxillofacial Surgery National Insurance Company (OMSNIC) can be used for estimations, and this database includes 39,392,008 cases [9]. The OMSNIC has estimated that 113 cases of death or brain injury occurred in dental office-based anesthesia practice (general anesthesia and sedation) during the 14-year period from 2000 to 2013 [9]. The incidence of death was estimated as 0.03/10,000 cases. These estimates are much older than our data; thus, a direct comparison cannot be made. Since our case number is much smaller than that of the OMSNIC data, anesthesia-related deaths might be recognized if the number of dental anesthesia cases increases in Japan. The

incidence reported by OMSNIC does not include data from dentists who are not insured by the OMSNIC. Bennet et al. reported that if data from these dentists were to be added to the OMSNIC database, a conservative estimate of the number of deaths and brain injuries occurring during dental anesthesia would be in excess of 1 case per one month in the United States [9]. Therefore, the safety of dental anesthesia in Japan seems to compare favorably with that in the United States.

In our study, more than 50% of the anesthesia-related life-threatening events were reportedly caused by human error. The leading root cause of these human errors was errors in drug use. Drug errors have been reported to be the most common source of human errors [10]. Our results agreed with this previous report. The second most common root cause of human error was related to respiration management. One of the most distinctive and risky points in clinical dental anesthesia is that the anesthesia provider and the surgeon must share one airway. Therefore, the anesthesia provider might not be able to provide airway management instantly if the airway patency becomes impaired due to sedation. Means of improving airway safety during sedation without intratracheal intubation should always be considered.

The subjects of the present study were confined to those treated at JDSA training facilities. JDSA-accredited training facilities are well equipped and have adequate manpower, while facilities such as private dental clinics might not have similar resources. Hence, the safety of dental anesthesia provided by dental anesthesiologists at non-JDSA-accredited training facilities may not be consistent with the present results. Ideally, data on all cases treated by dentist anesthesiologists in Japan should be collected to determine the outcomes of dental anesthesiology accurately. In future JDSA studies, the participating facilities should be expanded to enable the collection of more data. However, the results of this study will provide a basis for benchmarking the safety of dental anesthesia not only in Japan, but also around the world.

Obtaining background information on the patients who experienced life-threatening events is very important in terms of understanding the characteristics of these life-threatening events. However, because our database did not link the life-threatening events with individual patient backgrounds, we cannot include this information at this time. Future JDSA studies will collect data in a manner that allows life-threatening events to be linked to individual patient backgrounds.

In conclusion, this is the first survey to examine the safety of dental anesthesia at 32 JDSA-accredited training facilities. The results of the present study are the first evidence supporting the safety of anesthetic management as performed by dental anesthesiologists in Japan. To confirm changes in safety over time, this JDSA survey should be implemented on a regular basis.

Acknowledgements The authors would like to thank all members of the 15th-18th terms of the Database Construction Working Group of the JDSA.

Author contributions T.M. and T.I. conceived and designed research; T.S. and T.M. performed experiments; T.S. and T.M. analyzed data; T.S., T.M. and T.I. interpreted results of experiments; T.S., T.M. and T.I. drafted manuscript; T.S., T.M. and T.I. edited and revised manuscript; T.S., T.M. and T.I. approved final version of manuscript.

Data Availability All source data to perform the present study are available after a justified request to the Japanese Dental Society of Anesthesiology.

Declarations

Competing interests The authors declare no competing interests.

Ethics approval After approval from the ethics committee of the Japanese Dental Society of Anesthesiology (approval numbers: 1920-3 and 1920-4), the survey was also approved by the individual ethics committees of each accredited facility.

Consent to participate Not applicable. Data collection and analysis was retrospective from existing databases.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Weaver JM (2019) The History of the Specialty of Dental Anesthesiology. Anesth Prog 66:61–68. https://doi.org/10.2344/anpr-66-02-12
2. Orr DL 2nd (2013) The development of anesthesiology in oral and maxillofacial surgery. Oral Maxillofac Surg Clin North Am 25:341–355. https://doi.org/10.1016/j.coms.2013.04.003
3. Ash HL (1985) Anesthesia's dental heritage (William Thomas Green Morton). Anesth Prog 32:25–29
4. Matsuura H (1993) Modern history of dental anesthesia in Japan. Anesth Prog 40:109–113
5. Morimatsu H, Accidental Event (Pulmonary Embolism) Working Group, Safety Committee of the Japanese Society of Anesthesiologists (2021) Incidence of accidental events during anesthesia from 2012 to 2016: survey on anesthesia-related events by the Japanese Society of Anesthesiologists. J Anesth 35:206–212. https://doi.org/10.1007/s00540-021-02898-9
6. Gong CL, Hu JP, Qiu ZL, Zhu QQ, Hei ZQ, Zhou SL, Li X (2018) A study of anaesthesia-related cardiac arrest from a Chinese tertiary hospital. BMC Anesthesiol 18:127. https://doi.org/10.1186/s12871-018-0593-6
7. Sobreira-Fernandes D, Teixeira L, Lemos TS, Costa L, Pereira M, Costa AC, Couto PS (2018) Perioperative cardiac arrests - A subanalysis of the anesthesia-related cardiac arrests and associated mortality. J Clin Anesth 50:78–90. https://doi.org/10.1016/j.jclinane.2018.06.005

8. Nunnally ME, O'Connor MF, Kordylewski H, Westlake B, Dutton RP (2015) The incidence and risk factors for perioperative cardiac arrest observed in the national anesthesia clinical outcomes registry. Anesth Analg 120:364–370
9. Bennett JD, Kramer KJ, Bosack RC (2015) How safe is deep sedation or general anesthesia while providing dental care? J Am Dent Assoc 146:705–708. https://doi.org/10.1016/j.adaj.2015.04.005
10. Orser BA (2001) Medication safety in anesthetic practice: first do no harm. Can J Anaesth 47:1051–1054. https://doi.org/10.1007/BF03027954