European Journal of Medical Research

RESEARCH

Open Access

Sedation for transthoracic echocardiography in children with Down syndrome: a propensity score-weighted retrospective cohort study

Jie Hu[1], Lu Wang[1], Bing Xue[1], Ying Zhang[1] and Ruidong Zhang[1*]

Abstract

Background Transthoracic echocardiography can be performed under sedation in children with Down syndrome who have neurological or behavioral problems. This study aimed to compare the efficacy and safety of intranasal dexmedetomidine and oral chloral hydrate in children with Down syndrome who are undergoing transthoracic echocardiography.

Methods This retrospective cohort study reviewed the electronic medical records of patients with Down syndrome who underwent transthoracic echocardiography under oral chloral hydrate or intranasal dexmedetomidine sedation between June 2014 and September 2021. The patients were divided into oral chloral hydrate and intranasal dexmedetomidine groups according to the main agents used for sedation. The primary endpoint was the outcome of single-dose sedative agents, and the groups were compared using a propensity score weighting analysis.

Results In total, 149 patients (chloral hydrate group, n = 75; dexmedetomidine group, n = 74) were included in the final analysis. After propensity score weighting, 150 and 148 patients were included in the chloral hydrate and dexmedetomidine groups, respectively. The success rate of the initial sedative medication was significantly higher in the dexmedetomidine group than in the chloral hydrate group (89.1% vs. 80.7%, $p = 0.0412$) after adjustment for propensity score weighting. The success rate of the final sedative medication was higher in the dexmedetomidine group than in the chloral hydrate group (before propensity score weighting, 98.7% vs. 86.7%; after propensity score weighting, 98.5% vs. 86.8%; both p values < 0.01). Before and after propensity score weighting, the incidence of bradycardia during sleep was significantly higher in the dexmedetomidine group than in the chloral hydrate group. Sedation with dexmedetomidine or chloral hydrate was not associated with severe oxygen desaturation in children with Down syndrome.

Conclusions Compared with oral 50 mg/kg chloral hydrate, the use of a single intranasal dose of 2 μg/kg dexmedetomidine was related to a significantly higher success rate of sedation without increasing severe hypoxic events in children with Down syndrome undergoing transthoracic echocardiography, except for the incidence of bradycardia.

Keywords Children, Chloral hydrate, Dexmedetomidine, Down syndrome, Sedation

Background

Congenital heart disease (CHD) occurs in approximately 44% of children with Down syndrome (DS), and transthoracic echocardiography (TTE) assessments are frequently required for patients with DS [1]. However, developmental delays and behavioral abnormalities often preclude

*Correspondence:
Ruidong Zhang
doctorruidong@163.com
[1] Department of Anesthesiology, Shanghai Children's Medical Center, School of Medicine, Shanghai Jiaotong University, Shanghai 200127, China

patient cooperation, and sedation is often required in children with DS.

Chloral hydrates, the oldest synthetic hypnotics, are commonly used for the induction of sedation for pediatric patients during painless procedures. Traditionally, children with DS undergo TTE scans under oral chloral hydrate sedation in our hospital. However, the use of chloral hydrates has an increased rate of sedation failure, especially in younger and neurologically impaired children [2]. Patients with DS also face the disadvantages of chloral hydrate, such as bitter caustic taste, unpredictable onset, carcinogenicity, and genotoxicity [3].

Dexmedetomidine, a highly selective α_2-receptor agonist with central sedative and anxiolytic effects, has been widely used for pediatric sedation for nonpainful procedures [4]. Furthermore, intranasal dexmedetomidine avoids the hepatic first-pass effect, preserves higher bioavailability, and rapidly reaches the central nervous system [5]. Several studies have shown that intranasal dexmedetomidine is possibly a more effective sedation method for children undergoing diagnostic procedures than oral chloral hydrate [6, 7]; however, whether intranasal dexmedetomidine is a more optimal choice for sedation during TTE scans in children with DS remains unknown. Therefore, we aimed to evaluate the efficacy and safety of intranasal dexmedetomidine for TTE in children with DS compared with oral chloral hydrate and to provide a reference for clinical sedative use in this scenario.

Methods

Study design

This is a single-center, propensity score-weighted, retrospective cohort. Our study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

Patient selection

All data were collected from the electronic medical records at our institution. Outpatients with DS who had heart murmur or known CHD underwent either oral chloral hydrate or intranasal dexmedetomidine sedation for TTE between June 2014 and September 2021 were included in the study. Patients were divided into two groups according to the main sedative agent used: oral chloral hydrate or intranasal dexmedetomidine. Children with incomplete data, with second- or third-degree atrioventricular block, or who recently received digoxin or beta-blockers were excluded.

Sedation protocol

All patients were fasted for food, breast milk, formula, or clear liquids for 2 h. The patients in the chloral hydrate group received 50 mg/kg oral chloral hydrate. The patients in the dexmedetomidine group received 2 μg/kg intranasal dexmedetomidine (Yangtze River Pharmaceutical Ltd. Co. Jiangsu, China; 100 μg/mL). A certified sedation nurse administered the medications and monitored the patients. Modified Ramsay scale was used for sedation level measurement, and sedation level for TTE was successful once a modified Ramsay sedation score ≥ 3 was achieved [8]. Failure of sedation was defined as a modified Ramsay scale score < 3 if the initial sedation was inadequate at 30 min post-administration. The choice of the rescue method was at the discretion of the pediatric anesthesiologist.

Heart rate (HR) and pulse oxygen saturation (SpO_2) were used as standard monitoring indicators during echocardiography. According to experience, blood pressure measurements arouse sedation in children due to cuff inflation, and it was not routinely used in our clinical practice. After completion of the TTE scan, the patients were transferred to the post-anesthesia care unit (PACU) until they awoke spontaneously. Satisfactory discharge criteria included a modified Aldrete score ≥ 9 [9], interaction with parents and nurses, and HR and SpO_2 within normal ranges for age or at baseline.

Study endpoints

The primary endpoint was the outcome for single-dose sedation. Secondary outcomes included the final sedative medication outcome, incidence of rescue sedative medication, time to fall asleep, awakening time, periprocedural vital signs such as HR and SpO_2, and adverse events.

Time to fall asleep was defined as the time from sedative administration until falling asleep, and awakening time was defined as the time from completion of the TTE scan until discharge from the PACU. Periprocedural HR and SpO_2 were continuously monitored at the following time intervals: pre-administration, falling asleep, completion of the TTE scan, and recovery in the PACU.

Periprocedural adverse events, such as bradycardia and oxygen desaturation, were identified from electronic medical records. Bradycardia was defined as an HR less than the lower limit of normal awake HR (80 bpm for infants and children ≤ 5 years, 75 bpm for children aged 6–7 years, 70 bpm for children ≥ 8 years) [10]. The patients with DS who developed severe bradycardia after sedative medication were given atropine 0.01 mg/kg. Oxygen desaturation was defined as $SpO_2 < 92\%$ for children with left-to-right shunt CHD or 5% below baseline for children with right-to-left shunt CHD [10]. Severe hypoxia was corrected by nasal cannula oxygen therapy and airway maneuvers.

Covariates

We collected the demographic data, including age, weight, sex, and fasting time, of patients with DS. We evaluated the presence of underlying CHD by reviewing the electronic medical records of the patients and classifying patients with DS according to the type of CHD. Simple cases included atrial septal defects, ventricular septal defects, patent ductus arteriosus, and non-CHD patients with DS. Complex cases include tetralogy of Fallot, pulmonary stenosis, pulmonary atresia, complete atrioventricular canal, double-outlet right ventricle, congenital mitral regurgitation, and CHD-associated pulmonary hypertension.

Statistical analyses

Statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA) and R version 4.0.4 (R Foundation for Statistical Computing, Vienna, Austria). The inverse probability of treatment weighting (IPTW) method was used for propensity score weighting (PSW) to account for confounders, including age, sex, weight, type of CHD, and fasting time. The standardized mean difference (SMD) was used to evaluate balance at baseline between two groups, and an SMD ≤ 0.1 for covariates indicated sufficient balance.

The Kolmogorov–Smirnov test was used to assess the normality of continuous variables. Continuous variables with a normal distribution were expressed as mean ± standard deviation, whereas continuous variables with a non-normal distribution were expressed as median [interquartile range]. Categorical variables are expressed as numbers (percentages). Continuous data were compared using the independent-samples *t*-test or Mann–Whitney *U* test. Categorical variables were compared using the chi-squared test. A p-value < 0.05 was considered statistically significant.

Results

Demographics characteristics

Over the last 7 years, 152 pediatric patients with DS underwent TTE under sedation at our hospital. After assessing for eligibility, we excluded one patient without complete electronic medical records, one patient with second- and third-degree atrioventricular block, and one patient with co-administration of digoxin. In total, 149 patients (chloral hydrate group, n = 75; dexmedetomidine group, n = 74) were included in the final analysis (Fig. 1).

The demographic characteristics of the two study populations in terms of age, sex, weight, CHD type, and fasting duration are presented in Table 1. The median age of the patients was significantly younger in the chloral hydrate group than in the dexmedetomidine group (11 [15] vs. 16.5 [15] months, $p = 0.027$). After IPTW adjustment for the propensity score, the standard mean difference for all baseline variables was < 0.1, indicating that the weighted populations in both groups were comparable.

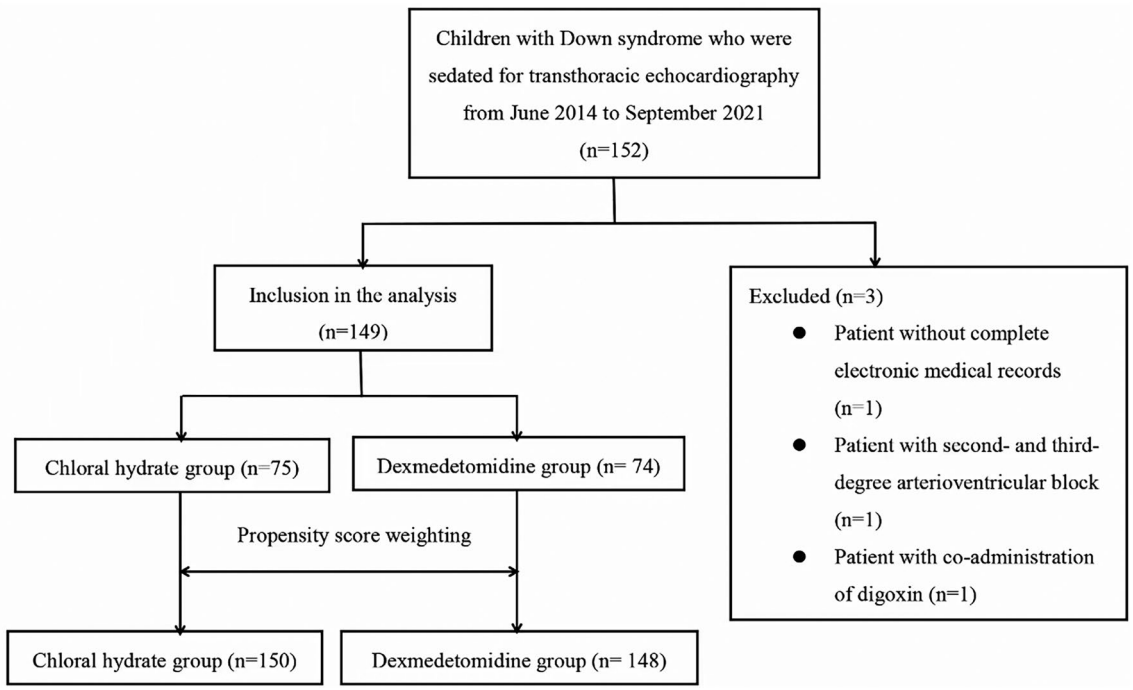

Fig. 1 Flow diagram

Table 1 Patients' baseline characteristics

Variables	Unweighted study population						Weighted study population					
	All cohort (n = 149)	Chloral hydrate group (n = 75)	Dexmedetomidine group (n = 74)	Statistic	p Value	SMD	All cohort (n = 298)	Chloral hydrate group (n = 150)	Dexmedetomidine group (n = 148)	Statistic	p Value	SMD
Age (months)	14 [8–24]	11 [7–22]	16.5 [9–24]	2.21	0.027	0.11	15 [8–24]	12 [7–24]	16 [9–24]	− 0.41	0.6794	0.03
Weight (kg)	8 [6.5–11]	7 [6–10]	9 [7–11]	1.69	0.09	0.15	8 [6.5–11]	7.5 [6–11]	9 [6.6–11]	0.93	0.3534	0.03
Sex												
Male	73 (49)	36 (48)	37 (50)	0.06	0.8071	0.04	147 (49.3)	74 (49.4)	73 (49.3)	0.00	0.981	< 0.01
Female	76 (51)	39 (52)	37 (50)				151 (50.7)	76 (50.6)	75 (50.7)			
Type of CHD												
Simple cases	84 (56.4)	43 (57.3)	41 (55.4)	0.06	0.8125	0.04	167 (55.9)	84 (55.8)	83 (56)	0.00	0.9726	< 0.01
Complex cases	65 (43.6)	32 (42.7)	33 (44.6)				131 (44.1)	66 (44.2)	65 (44)			
Fasting time												
≤ 3 h	91 (61.1)	44 (58.7)	47 (63.5)	0.37	0.5441	0.1	182 (61.1)	91 (61)	91 (61.3)	0.00	0.9477	0.01
> 3 h	58 (38.9)	31 (41.3)	27 (36.5)				116 (38.9)	58 (39)	57 (38.7)			

Data are expressed as median [interquartile range] (for continuous variables) and n (%) (for categorical variables). SMD, standardized mean difference; CHD, congenital heart disease

Table 2 Results after sedative administration

Variables	Pre-weighted analysis					Post-weighted analysis				
	All cohort (n = 149)	Chloral hydrate group (n = 75)	Dexmedetomidine group (n = 74)	Statistic	*p* Value	All cohort (n = 298)	Chloral hydrate group (n = 150)	Dexmedetomidine group (n = 148)	Statistic	*p* Value
Outcome of initial sedative medication										
Successful	127 (85.2)	61 (81.3)	66 (89.2)	1.83	0.1765	253 (84.9)	121 (80.7)	132 (89.1)	4.17	0.0412
Unsuccessful	22 (14.8)	14 (18.7)	8 (10.8)			45 (15.1)	29 (19.3)	16 (10.9)		
Outcome of final sedative medication										
Successful	138 (7.4)	65 (86.7)	73 (98.7)	7.82	< 0.01	276 (92.6)	130 (86.8)	146 (98.5)	15.1	< 0.01
Unsuccessful	11 (43.6)	10 (13.3)	1 (1.4)			22 (7.4)	20 (13.2)	2 (1.5)		
Rescue sedative medication										
Yes	17 (11.4)	9 (12)	8 (10.8)	0.05	0.8194	35 (61.1)	19 (12.4)	16 (10.9)	0.6708	0.18
No	132 (88.6)	66 (88)	66 (89.2)			263 (38.9)	131 (87.6)	132 (89.1)		
Time to fall asleep (min)	15 [15–23]	15 [15–25]	15 [14–20]	1.16	0.2454	15 [15–23]	15 [15–25]	15 [14–20]	0.63	0.5306
Awakening time (min)	20 [5–40]	25 [5–40]	20 [5–35]	0.41	0.6799	20 [5–40]	28 [5–40]	20 [5–35]	0.80	0.4230

Data are expressed as median [interquartile range] (for continuous variables) and n (%) (for categorical variables)

Sedation outcomes

The post-sedative outcomes of the unweighted and weighted groups are presented in Table 2. In the unweighted population, there was no significant difference in the success rate of the initial sedative medication between the groups (89.2% in the dexmedetomidine group vs. 81.3% in the chloral hydrate group, $p=0.1765$). After adjusting for PSW, the success rate of initial sedative medication (89.1% in the dexmedetomidine group vs. 80.7% in the chloral hydrate group, $p=0.0412$) was significantly different between the groups. In the weighted population, the success rate of the final sedative medication was higher in the dexmedetomidine group than in the chloral hydrate group (98.5% in the dexmedetomidine group vs. 86.8% in the chloral hydrate group, $p<0.01$), and the results after PSW were similar to those observed before PSW. The rescue sedative rate, time to fall asleep, and awakening time showed no differences between the unweighted and weighted populations.

Vital signs and complications

Table 3 presents the vital signs after sedative administration in both groups. In both the unweighted and weighted populations, the HR in the dexmedetomidine group was significantly slower than that in the chloral hydrate group, from falling asleep to recovery in the PACU. The overall SpO_2 did not differ between the groups in either the unweighted or weighted populations.

The post-sedative complications are presented in Table 4. Before and after PSW, bradycardia occurred more frequently in the dexmedetomidine group than in the chloral hydrate group, from falling asleep to finishing the TTE scan; atropine was not administered in either group. The HR returned to normal in all cases after awakening. The total oxygen desaturation rate did not differ between groups in the unweighted and weighted populations. All patients with desaturation were corrected using a simple oxygen blow, and none required further airway maneuvers or treatment.

Discussion

In the present study, the patients receiving chloral hydrate were younger than those receiving dexmedetomidine. We explained treatment-related baseline differences using the propensity score weighting method and found that the use of dexmedetomidine was significantly associated with a higher rate of successful initial sedation and a higher incidence of bradycardia.

Patients with DS experience repeated exposure to sedatives because TTE assessments are performed early in life. Chloral hydrate can trigger widespread neurodegeneration in immature animal brains, and repeated exposure in children younger than 3 years may affect brain development [11]. Currently, the US Food and Drug Administration recommends the use of dexmedetomidine for sedation to avoid possible untoward long-term neurologic effects of sedatives [12].

In our study, the success rate of a single dose of dexmedetomidine sedation in patients with DS was significantly higher than that of chloral hydrate in the weighted population, which is inconsistent with a previous study [13]. In that study, Miller et al. found that oral 70 mg/kg chloral hydrate, which is higher than the dose used in our study, to be as effective as intranasal 2 μg/kg dexmedetomidine for TTE sedation [13]. We also found that the efficacy of initial intranasal 2 μg/kg dexmedetomidine for TTE sedation (89.1%, after PSW), which is consistent with a previous study in similar pediatric patients with DS [10]. In that study, Miller et al. used a single intranasal dose of 2–2.5 μg/kg dexmedetomidine for TTE in patients with DS, and their patients were older than ours (median age, 31.1 vs. 16.5 months) [10]. Moreover, our study demonstrated that 2 μg/kg dexmedetomidine via the nasal route can provide similar effectiveness of sedation for TTE in infants and young toddlers with DS.

In the current study, the success rate of rescue sedation in dexmedetomidine group was higher than that in chloral hydrate group (98.5% vs. 86.8%) in the weighted populations whether before or after PSW, which is inconsistent with previous reports [14]. The study compared the efficacies of chloral hydrate and dexmedetomidine in rescuing failed chloral hydrate sedation. However, in our study, we focused on comparing the rescue methods for failed sedation with chloral hydrate or dexmedetomidine. These results may be attributed to the high incidence of nausea and vomiting associated with the unpleasant taste of chloral hydrate [15]. After a single dose of oral chloral hydrate, children often refuse the rescue medication because of its bitter caustic taste. In contrast, dexmedetomidine is odorless and non-irritating, and its intranasal administration is easily tolerated by children. Hence, the taste of drugs has been postulated to be the likely cause of differences in the success rate of rescue sedation.

The present study revealed that the HR decreases from baseline were more significant under intranasal dexmedetomidine sedation than under oral chloral hydrate sedation. The incidence of bradycardia after sedative administration was higher in the dexmedetomidine group than in the chloral hydrate group. These findings are inconsistent with a previous study that reported that age-defined bradycardia was uncommon in patients with DS younger than 24 months under intranasal dexmedetomidine sedation [10]. Dexmedetomidine is associated with a higher risk of bradycardia, the most frequently reported adverse event [16]. Patients with DS have impaired autonomic function, which blunts vagal modulation and

Table 3 Vital signs after sedative administration

Variables	Pre-weighted analysis					Post-weighted analysis				
	All cohort (n = 149)	Chloral hydrate group (n = 75)	Dexmedetomidine group (n = 74)	Statistic	*p* Value	All cohort (n = 298)	Chloral hydrate group (n = 150)	Dexmedetomidine group (n = 148)	Statistic	*p* Value
Heart rate (bpm)										
Pre-administration	126.9 ± 21.0	128.8 ± 20.8	125.0 ± 21.0	1.11	0.2697	126.6 ± 29.8	127.6 ± 29.7	125.5 ± 30.0	0.62	0.5370
Falling asleep	105.3 ± 19.5	112.1 ± 17.4	98.9 ± 19.3	4.26	< 0.001	105.0 ± 27.6	110.8 ± 25.5	99.6 ± 27.5	3.54	< 0.001
Finishing TTE scan	106.8 ± 24.6	114.2 ± 22.8	100.2 ± 24.5	3.4	< 0.001	106.5 ± 34.6	112.7 ± 32.9	101.0 ± 34.5	2.83	0.005
Recovery at PACU	121.2 ± 22.3	129.0 ± 21.5	114.3 ± 20.8	3.95	< 0.001	120.8 ± 31.3	127.8 ± 30.7	114.6 ± 29.4	3.55	< 0.001
SpO_2 (%)										
Pre-administration	93.6 ± 5.6	93.8 ± 4.9	93.4 ± 6.2	0.52	0.6052	93.6 ± 7.9	93.9 ± 7.0	93.4 ± 8.8	0.59	0.5544
Falling asleep	94.2 ± 4.1	93.8 ± 4.7	94.5 ± 3.4	− 1.03	0.3036	94.2 ± 5.8	93.9 ± 6.7	94.5 ± 4.8	− 0.91	0.3620
Finishing TTE scan	94.5 ± 4.4	94.4 ± 4.4	94.6 ± 4.4	− 0.21	0.8378	94.5 ± 6.2	94.5 ± 6.1	94.6 ± 6.3	− 0.08	0.9339
Recovery at PACU	95.0 ± 4.1	94.7 ± 4.5	95.3 ± 3.7	− 0.87	0.3879	95.0 ± 5.7	94.8 ± 6.3	95.3 ± 5.2	− 0.70	0.4851

Data are expressed as mean ± standard deviation

TTE, transthoracic echocardiography; PACU, post-anesthesia care unit; SpO_2, pulse oxygen saturation

Table 4 Complications after sedative administration

Variables	Outcome	Pre-weighted analysis					Post-weighted analysis				
		All cohort (n = 149)	Chloral hydrate group (n = 75)	Dexmedetomidine group (n = 74)	Statistic	p Value	All cohort (n = 298)	Chloral hydrate group (n = 150)	Dexmedetomidine group (n = 148)	Statistic	p Value
Bradycardia (%)											
Falling asleep	Yes	16 (11.4)	4 (5.9)	12 (16.4)	3.9	0.0483	32 (11.4)	9 (7.0)	23 (15.4)	5.02	0.0251
	No	125 (88.7)	64 (94.1)	61 (83.6)			250 (88.6)	126 (93.0)	124 (84.6)		
	Total	141	68	73			282	135	147		
Finishing TTE scan	Yes	20 (15.0)	5 (8.1)	15 (21.1)	4.42	0.0355	41 (15.3)	12 (9.8)	29 (20.1)	5.49	0.0191
	No	113 (85.0)	57 (91.9)	56 (78.9)			225 (84.7)	112 (90.3)	114 (79.9)		
	Total	133	62	71			266	124	142		
Recovery at PACU	Yes	3 (2.3)	1 (1.6)	2 (2.9)	0.22	0.6421	7 (2.5)	2 (1.8)	4 (3.2)	0.45	0.5027
	No	128 (97.7)	60 (98.4)	68 (97.1)			255 (97.5)	120 (98.2)	135 (96.9)		
	Total	131	61	70			262	122	140		
Oxygen desaturation (%)											
Falling asleep	Yes	0 (0.0)	0 (0.0)	0 (0.0)	0.00	1.00	0 (0.0)	0 (0.0)	0 (0.0)	0.00	1.00
	No	144 (100)	70 (100)	74 (100)			282 (100)	136 (100)	146 (100)		
	Total	144	70	74			282	136	146		
Finishing TTE scan	Yes	3 (2.2)	1 (1.6)	2 (2.8)	0.21	0.6495	6 (2.4)	2 (1.4)	5 (3.3)	1.01	0.3150
	No	131 (97.8)	61 (98.4)	70 (97.2)			261 (97.6)	122 (98.6)	139 (96.7)		
	Total	134	62	72			268	124	144		
Recovery at PACU	Yes	4 (3.0)	3 (4.9)	1 (1.4)	1.34	0.2469	8 (2.9)	6 (4.7)	2 (1.4)	2.40	0.1213
	No	127 (97.0)	58 (95.1)	69 (98.6)			254 (97.1)	116 (95.4)	138 (98.6)		
	Total	131	61	70			262	122	140		

Data are expressed as n (%) (for categorical variables). As the weight of the observation may not be an integer, the count of each group may be fewer or more than the total of all the groups after rounding off

TTE, transthoracic echocardiography; PACU, post-anesthesia care unit

attenuates the HR response. The response of the HR in patients with DS to sympathetic stimulation is weakened, which may partially result in chronotropic incompetence [17]. In our study, impaired autonomic cardiac regulation was the reason patients with DS showed pronounced bradycardia after dexmedetomidine administration. Hence, we should be aware that patients with DS are more prone to exhibit bradycardia during dexmedetomidine administration.

In this study, none of the patients with DS experienced severe desaturation or required advanced airway inventions after nasal dexmedetomidine administration, which is consistent with a previous study [10]. Compared with most other sedatives, dexmedetomidine has minimal effects on respiratory drive, airway patency, and tone and seems to be devoid of clinically significant respiratory adverse events [18, 19]. However, respiratory control in patients with DS can be adversely affected by various factors, including autonomic dysfunction, multilevel airway collapse, gastroesophageal reflux, and lower respiratory considerations [20]. Thus, clinicians should be aware of the potential adverse respiratory effects of dexmedetomidine in children with DS.

This study has limitations. First, the lack of randomization and the choice of sedative administration may represent a selection bias. Second, the uniform protocol for the choice of rescue sedative methods may have varied in patients with DS owing to the retrospective nature of the study. Third, blinding procedures were not used to evaluate the adverse effects of sedatives administered by medical staff (i.e., anesthesiologists and nurses). Fourth, the applicability of our results cannot be generalized to other centers because the data were collected from a single tertiary hospital. In the future, prospective, multicenter, randomized controlled trials are needed to validate these findings and to eliminate biases associated with retrospective trials.

Conclusions

This retrospective observational study showed that a single intranasal dose of 2 μg/kg dexmedetomidine appeared to be more effective than oral 50 mg/kg chloral hydrate for sedation in children with DS who are undergoing TTE. Our study established a theoretical foundation for recommendation of dexmedetomidine as a suitable alternative sedative for TTE in children with DS, despite the incidence of bradycardia.

Abbreviations

CHD	Congenital heart disease
DS	Down syndrome
HR	Heart rate
IPTW	Inverse probability of treatment weighting
PACU	Post-anesthesia care unit
PSW	Propensity score weighting
SMD	Standardized mean difference
SpO_2	Pulse oxygen saturation
TTE	Transthoracic echocardiography

Acknowledgements

We thank Editage (www.editage.cn) for the English language editing.

Author contributions

Authors' contributions Conceptualization and design: RZ and BX; project administration: RZ; resources: JH and LW; data curation: YZ; formal analysis: RZ; writing: all authors. All authors approved the final version of the manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Shanghai Children's Medical Center in China (approval number: SCMCIRB-K2022087-1; July 1, 2022). The requirement for informed consent was waived by institutional review board of Shanghai Children's Medical Center, as the data used were anonymized.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 17 December 2024 Accepted: 27 April 2025
Published online: 16 May 2025

References

1. Bull MJ. Down syndrome. N Engl J Med. 2020;382:2344–52.
2. Rumm PD, Takao RT, Fox DJ, Atkinson SW. Efficacy of sedation of children with chloral hydrate. South Med J. 1990;83:1040–3.
3. Cozzi G, Norbedo S, Barbi E. Intranasal dexmedetomidine for procedural sedation in children, a suitable alternative to chloral hydrate. Paediatr Drugs. 2017;19:107–11.
4. McMorrow SP, Abramo TJ. Dexmedetomidine sedation: uses in pediatric procedural sedation outside the operating room. Pediatr Emerg Care. 2012;28:292–6.
5. Miller JW, Balyan R, Dong M, Mahmoud M, Lam JE, Pratap JN, et al. Does intranasal dexmedetomidine provide adequate plasma concentrations for sedation in children: a pharmacokinetic study. Br J Anaesth. 2018;120:1056–65.
6. Cao Q, Lin Y, Xie Z, Shen W, Chen Y, Gan X, et al. Comparison of sedation by intranasal dexmedetomidine and oral chloral hydrate for pediatric ophthalmic examination. Paediatr Anaesth. 2017;27:629–36.
7. Reynolds J, Rogers A, Medellin E, Guzman JA, Watcha MF. A prospective, randomized, double-blind trial of intranasal dexmedetomidine and oral chloral hydrate for sedated auditory brainstem response (ABR) testing. Paediatr Anaesth. 2016;26:286–93.
8. Agrawal D, Feldman HA, Krauss B, Waltzman ML. Bispectral index monitoring quantifies depth of sedation during emergency department procedural sedation and analgesia in children. Ann Emerg Med. 2004;43:247–55.
9. Aldrete JA. Postanesthesia recovery scores and postoperative hypoxemia. Anesth Analg. 1988;67:1016–7.

10. Miller J, Ding L, Spaeth J, Lam J, Paquin J, Lin E, et al. Sedation methods for transthoracic echocardiography in children with trisomy 21—a retrospective study. Paediatr Anaesth. 2017;27:531–9.
11. Istaphanous GK, Loepke AW. General anesthetics and the developing brain. Curr Opin Anaesthesiol. 2009;22:368–73.
12. Olutoye OA, Baker BW, Belfort MA, Olutoye OO. Food and Drug Administration warning on anesthesia and brain development: implications for obstetric and fetal surgery. Am J Obstet Gynecol. 2018;218:98–102.
13. Miller J, Xue B, Hossain M, Zhang MZ, Loepke A, Kurth D. Comparison of dexmedetomidine and chloral hydrate sedation for transthoracic echocardiography in infants and toddlers: a randomized clinical trial. Paediatr Anaesth. 2016;26:266–72.
14. Zhang W, Wang Z, Song X, Fan Y, Tian H, Li B. Comparison of rescue techniques for failed chloral hydrate sedation for magnetic resonance imaging scans—additional chloral hydrate vs intranasal dexmedetomidine. Paediatr Anaesth. 2016;26:273–9.
15. Chung T, Hoffer FA, Connor L, Zurakowski D, Burrows PE. The use of oral pentobarbital sodium (Nembutal) versus oral chloral hydrate in infants undergoing CT and MR imaging—a pilot study. Pediatr Radiol. 2000;30:332–5.
16. Keating GM. Dexmedetomidine: a review of its use for sedation in the intensive care setting. Drugs. 2015;75:1119–30.
17. Ueno K, Ninomiya Y, Shiokawa N, Hazeki D, Eguchi T, Kawano Y. Dexmedetomidine is associated with an increased incidence of bradycardia in patients with trisomy 21 after surgery for congenital heart disease. Pediatr Cardiol. 2016;37:1228–34.
18. Mahmoud M, Mason KP. Dexmedetomidine: review, update, and future considerations of paediatric perioperative and periprocedural applications and limitations. Br J Anaesth. 2015;115:171–82.
19. Mason KP, Lerman J. Dexmedetomidine in children: current knowledge and future applications. Anesth Analg. 2011;113:1129–42.
20. Sinton JW, Cooper DS, Wiley S. Down syndrome and the autonomic nervous system, an educational review for the anesthesiologist. Paediatr Anaesth. 2022;32:609–16.

Publisher's Note