Dexmedetomidine and Ketamine Sedation for Dental Extraction in Children With Cyanotic Heart Disease

M. Shahnaz Hasan, MBBS, M Anes,* and Lucy Chan, MBBS, FANZCA

Treating children with cyanotic congenital heart disease poses many challenges to anesthesiologists because of the multiple problems associated with the condition. The anesthetic technique and drugs used perioperatively can affect a patient’s physiologic status during surgery. The adherence to certain hemodynamic objectives and the avoidance of factors that could worsen the abnormal cardiopulmonary physiology cannot be overemphasized. In the present case series, we describe the use of a dexmedetomidine-ketamine combination for dental extraction in spontaneously breathing children with cyanotic congenital heart disease. The anesthetic concerns regarding airway management, the pharmacologic effects of drugs, and maintenance of adequate hemodynamic, blood gases, and acid-base status are discussed.

The incidence of congenital heart disease (CHD) has varied from 4/1,000 to 50/1,000 live births.1 Through improved medical and surgical interventions, anesthesiologists will encounter more such children for noncardiac surgery. Some of the problems with CHD include chronic hypoxemia and a risk of brain abscess, pulmonary hypertension, and bacterial endocarditis. The presence of severe chronic hypoxemia raises concerns, such as polycythemia, coagulation abnormalities, and increased blood viscosity and sympathetic tone.

Although physiologically, well-compensated children can undergo dental extraction with minimal risk, those with severe cyanotic CHD will be at greater risk. Cyanosis can develop in lesions with right-to-left shunting, resulting in a reduction of pulmonary blood flow (tetralogy of Fallot, Eisenmenger complex), mixing of the systemic and pulmonary venous return (single ventricle, transpositions of great vessels), and primarily obstructed blood flow (pulmonary stenosis).

No ideal anesthetic technique exists for specific lesions; however, adherence to general hemodynamic objectives will ensure a successful outcome.2 We describe 3 children with cyanotic CHD who underwent dental extraction while breathing spontaneously after dexmedetomidine and ketamine administration. The children’s parents provided permission to publish our report.

Case Reports

PATIENT 1

A 4-year-old, 12.6-kg boy with Down syndrome required dental extraction 1 month before his cardiac corrective surgery. He had been diagnosed with tetralogy of Fallot during the neonatal period that was characterized by a large septal defect, severe pulmonary stenosis, tricuspid regurgitation, and pulmonary hypertension. An echocardiogram had shown a large ventricular septal defect, measuring 10 mm, with a bidirectional shunt noted. His pulmonary stenosis gradient was 71 mm Hg. He also had mild tricuspid regurgitation (TR), with a jet of 59 mm Hg. The left ventricular ejection fraction (LVEF) was 81%, and the left ventricular fractional shortening (LVFS) was 50%.
On examination, a grade 3 pansystolic murmur was found over the left sternal edge, with a loud second heart sound. Blood investigations showed polycythemia. He came to the operating theater with intravenous (IV) maintenance fluids. Basic monitoring devices were connected to the patient. His baseline oxygen saturation (SpO₂) was 78% (room air), and his blood pressure (BP) and heart rate (HR) was 132/83 mm Hg and 95 bpm, respectively. He received endocarditis prophylaxis and IV atropine before the procedure. Hydration was continued with Hartmann's solution at 7 mL/kg/hr.

An infusion of dexmedetomidine, 1 μg/kg, for 10 minutes was started, followed by a maintenance infusion titrated at 0.5 to 1.0 μg/kg/hr. A bolus dose of IV ketamine, 0.5 mg/kg, was given, followed by insertion of a nasopharyngeal airway for oxygen therapy. An arterial blood gas (ABG) sample was obtained (sample 1; Table 1). Another bolus of IV ketamine, 0.5 mg/kg, was given just before placement of the bite guard. The local anesthetic infiltration (4 mL lignocaine 2% with 1:100,000 adrenaline) was given by the surgeon. Ten carious teeth were extracted. The extraction sites were compressed and sutured to achieve hemostasis. Another bolus of IV ketamine, 0.5 mg/kg, was administered during the procedure, which required 25 minutes. The lowest BP and pulse rate recorded during the procedure was 110/70 mm Hg and 82 bpm, respectively (Table 2). The respiratory rate was 25 breaths/min, and the oxygen saturation was 94 to 99%. Two more ABG samples were taken during and after completion of the procedure (samples 4 and 5; Table 1), which required 25 minutes. He woke up 30 minutes after discontinuation of the dexmedetomidine infusion.

PATIENT 2

A 5-year-old, 14.6-kg boy with trisomy 21 also had cyanotic CHD (with pulmonary stenosis, an atrioventricular septal defect, and no pulmonary hypertension) and a surgically repaired imperforated anus. The echocardiogram showed large septal defects, measuring 9 mm for the ventricular septal defect and 24 mm for the atrial septal defect. The LVEF and LVFS was 78 and 43%, respectively, with a TR jet of 50 mm Hg. The pulmonary artery size was 11 mm. He had clubbing and was centrally cyanosed, with a saturation of 80 to 85% under room air. He showed no evidence of respiratory distress. His BP was 90/50 mm Hg, and his HR was 90 to 100 bpm. He had a precordial grade 4 systolic murmur. His blood test results showed polycythemia and thrombocytopenia (hemoglobin [Hb] 19.3 g/dL, hematocrit [Hct] 0.54, and platelet count 86 × 10⁹/L).

His perioperative management was similar to that for the first patient. Five teeth were extracted under dexmedetomidine infusion, and he received 2 additional boluses of IV ketamine. His blood pressure was 85/55 to 105/70 mm Hg, HR of 65 to 90 bpm (Table 2), respiratory rate of 28 breaths/min, and SpO₂ 95 to 99%. Two ABG samples were taken during and after completion of the procedure (samples 4 and 5; Table 1), which required 25 minutes. He woke up 30 minutes after discontinuation of the dexmedetomidine infusion.

Table 1. Serial ABG Results for Patients 1 and 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patient 1</th>
<th>Patient 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABG sample</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>pH</td>
<td>7.333</td>
<td>7.264</td>
</tr>
<tr>
<td>PₐO₂ (mm Hg)</td>
<td>125</td>
<td>106</td>
</tr>
<tr>
<td>PₐCO₂ (mm Hg)</td>
<td>33.4</td>
<td>43.9</td>
</tr>
<tr>
<td>Base excess</td>
<td>−7.5</td>
<td>−6.6</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>18.7</td>
<td>18.6</td>
</tr>
</tbody>
</table>

Abbreviations: ABG, arterial blood gas; PₐCO₂, partial pressure of carbon dioxide; PₐO₂, partial pressure of oxygen.

echocardiogram showed a 21-mm aorta and 2.5-mm pulmonary artery.

The intraoperative management was similar, with a dexmedetomidine-ketamine combination, as outlined for the first case. Six teeth were extracted within 25 minutes. Her respiratory rate was 25 to 30 breaths/min and SpO2 95 to 99%. Her BP was 80/55 to 115/75 mm Hg and HR 85 to 100 bpm (Table 2). She had regained consciousness 30 minutes after discontinuation of the dexmedetomidine infusion. No ABG sample was taken.

**Discussion**

Airway management in children with CHD for dental extraction can range from mask or laryngeal mask airway general anesthesia to endotracheal anesthesia. We treated 3 patients who received oxygen supplementation by way of a nasopharyngeal airway for dental extraction. Adequacy of the spontaneous respiration was guided by a capnograph tracing. The child’s head should be placed in a slight head-down position to avoid airway obstruction by secretions, blood, and debris, which should be removed by vigilant suction of the oral cavity. We ensured airway patency by supporting the mandible with the fingers and preventing the tongue from falling back. Sharing the airway with the dental surgeon will result in the additional hazard from dental packs or gauze that could obstruct the airway and, subsequently, breathing.

Remembering the special features of cyanotic CHD and understanding that pharmacologic agents can alter the physiologic status during surgery, we used dexmedetomidine and ketamine to provide an anesthetic for spontaneous breathing and analgesia during the dental treatment. The combined drug effect could avoid additional increases in right-to-left shunting and the consequent reductions in pulmonary blood flow.

Dexmedetomidine has been widely studied and still presents exciting possibilities for various groups of children as a procedural sedative. An increasing body of clinical evidence has supported the safety and benefit of dexmedetomidine in treating pediatric cardiac patients. However, it has limited analgesic property and will not routinely produce effective results when administered as the sole agent for painful procedures in children and adults.3,5

Dexmedetomidine has sympatholytic effects and commonly produces bradycardia and hypotension. The data are insufficient to address its effect on the pulmonary vascular bed. A rapid bolus of dexmedetomidine will produce transient increases in blood pressures, which will be more pronounced in the systemic vasculature than in the pulmonary.6 In a retrospective review, dexmedetomidine sedation did not increase the pulmonary vascular resistance for a post-Fontan procedure.7

Ketamine is a much older drug and has remained a particularly useful agent for pediatric anesthesia. It has significant analgesia and desirable anesthetic properties owing to its rapid onset and ability to preserve the airway reflexes. Its sympathomimetic effects will maintain systemic vascular resistance and cardiac contractility. Ketamine has minimal effects on the pulmonary vascular resistance and has been considered safe for children with pulmonary hypertension, provided the partial pressure of carbon dioxide (PaCO2) has been maintained within the normal range.8

However, its clinical usefulness has been limited by the presence of intraoperative cardiostimulatory signs and psychomimetic effects in the postoperative period. Many drugs have been studied in an effort to offset these undesirable features.9 Recent work has shown that dexmedetomidine premedication can effectively and safely attenuate the ketamine-induced hemodynamic pressor response and psychomimetic effects.10 Also, dexmedetomidine can prevent the emergence delirium and salivation that can occur with ketamine.11

The unfavorable pharmacodynamic profiles of both dexmedetomidine and ketamine become less problematic and a good balance can be achieved

<table>
<thead>
<tr>
<th>Measurement Point</th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Patient 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP (mm Hg)</td>
<td>HR (bpm)</td>
<td>BP (mm Hg)</td>
<td>HR (bpm)</td>
</tr>
<tr>
<td>Baseline</td>
<td>132/83</td>
<td>95</td>
<td>90/50</td>
</tr>
<tr>
<td>Start of procedure</td>
<td>130/82</td>
<td>98</td>
<td>105/65</td>
</tr>
<tr>
<td>10 minutes into procedure</td>
<td>145/85</td>
<td>95</td>
<td>85/60</td>
</tr>
<tr>
<td>20 minutes into procedure</td>
<td>120/79</td>
<td>98</td>
<td>102/70</td>
</tr>
<tr>
<td>End of procedure</td>
<td>110/70</td>
<td>100</td>
<td>105/69</td>
</tr>
<tr>
<td>In recovery</td>
<td>115/65</td>
<td>82</td>
<td>85/50</td>
</tr>
</tbody>
</table>

Abbreviations: BP, blood pressure; HR, heart rate.
when used together. This has been reported in infants and children undergoing cardiac catheterization.\textsuperscript{12,13}

This combination has also shown no adverse cardiovascular and respiratory effects in 3 children with trisomy 21 and obstructive sleep apnea.\textsuperscript{14}

The doses of ketamine and dexmedetomidine we have reported were considered acceptable, with a dexmedetomidine infusion rate of up to 1 $\mu$g/kg/hr. Three boluses (0.5 mg/kg) of ketamine were required. Slight changes occurred in the ABG parameters (Table 1), but no clinical consequences were noted. The oxygenation was satisfactory, and the greatest PaCO$_2$ observed was 43.9 mm Hg in patient 1. Each child received 7 mL/kg of Hartmann's solution during surgery to ensure adequate hydration. No hypoxia, hypercarbia, or acidosis developed, which would have a deleterious effect on the pulmonary vascular resistance. The children woke up without agitation within 20 to 30 minutes after the dexmedetomidine infusion had been discontinued.

Although individually, dexmedetomidine and ketamine will not produce a clinically significant increase in pulmonary pressure, additional studies to demonstrate a greater level of evidence are required to address the efficacy and safety of the combination on the systemic and pulmonary circulations.

The Food and Drug Administration has not approved the use of dexmedetomidine for pediatric patients in North America; thus, its use is off label. However, quite a number of reviews have been published recently on the use of dexmedetomidine in children.\textsuperscript{3,15} The anesthetic technique might seem feasible; however, we cannot overemphasize the importance of airway patency during surgery, and trained anesthetists are essential to manage these high-risk children.

In conclusion, we have come a long way from the first known general anesthetic with nitrous oxide administered for dental extraction by dentist Horace Wells in 1844. The present study is the first report that the dexmedetomidine-ketamine combination will be clinically safe and effective for children with cyanotic CHD undergoing multiple teeth extractions. With close cooperation and vigilance of the dental surgeon and careful attention to the pathophysiology and desired hemodynamic goals, it will be feasible to plan a dexmedetomidine-ketamine anesthetic technique for spontaneous ventilation in children with cyanotic CHD for dental extraction.

\section*{References}