# Senning Procedure in Adolescent With TGA-IVS: Anesthetic Strategy

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## ABSTRACT

**Introduction:** Transposition of the great arteries with intact ventricular septum (TGA-IVS) is typically corrected in infancy, with arterial switch operation (ASO) as the gold standard. Survival into adolescence is exceptionally rare and depends on adequate intercirculatory mixing through an atrial septal defect.

**Case Description:** This study presents a case of a 13-year-old adolescent with TGA-IVS who underwent the senning procedure as an alternative due to unsuitability for ASO. Anesthetic management included judicious selection of inotropes with milrinone and epinephrine, strict rhythm control, electrolyte optimization, and intraoperative transesophageal echocardiography (TEE) monitoring. Perioperative diagnosis revealed RV systolic pressure >⅔ of systemic, necessitating the senning procedure to redirect venous return at the atrial level. The patient was successfully managed with satisfactory clinical outcomes oxygen saturation >95% without arrhythmias at hospital discharge on postoperative day 7. Meticulous anesthetic management addressing systemic RV dysfunction and arrhythmia prevention proved crucial for surgical success.

**Conclusion:** This case emphasizes the significant role of anesthesiologists in managing this complex cardiac population, particularly in rare cases where anatomical repair is no longer feasible.

**Keywords**: Arrhythmia, atrial switch operation, right ventricular dysfunction, transposition of the great arteries

# Prosedur Senning pada Remaja dengan TGA-IVS: Strategi Anestesi

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***ABSTRAK***

***Pendahuluan:*** *Transposisi arteri besar dengan septum ventrikel utuh (TGA-IVS) biasanya diperbaiki pada masa bayi dengan operasi switch arteri (ASO) sebagai standar emas. Kelangsungan hidup hingga remaja sangat jarang dan bergantung pada pencampuran intrasirkulasi yang adekuat melalui defek septum atrium.*

***Deskripsi Kasus:*** *Penelitian ini menyajikan kasus remaja berusia 13 tahun dengan TGA-IVS yang menjalani prosedur senning sebagai alternatif karena ketidaksesuaian untuk ASO. Manajemen anestesi mencakup pemilihan inotrope yang bijaksana dengan milrinone dan epinefrin, kontrol irama ketat, optimalisasi elektrolit, dan pemantauan transesophageal echocardiography (TEE) intraoperatif. Diagnosis perioperatif menunjukkan RV sistol >⅔ tekanan sistemik, sehingga prosedur senning dipilih untuk mengalihkan aliran balik vena di level atrium. Pasien berhasil dirawat dengan hasil klinis yang memuaskan oksigenasi >95% tanpa aritmia saat keluar rumah sakit pada hari ke-7. Manajemen anestesi yang teliti untuk disfungsi RV sistemik dan pencegahan aritmia terbukti krusial untuk kesuksesan operasi.*

***Simpulan:*** *Kasus ini menekankan peran signifikan anestesiolog dalam mengelola populasi pasien jantung kompleks ini, khususnya dalam kasus langka di mana perbaikan anatomis tidak lagi dapat dilakukan.*

***Kata Kunci:*** *Aritmia, disfungsi ventrikel kanan, operasi pergantian atrium, transposisi arteri besar*

## INTRODUCTION

Transposition of the great arteries with intact ventricular septum (TGA-IVS) represents a cyanotic heart defect requiring prompt surgical intervention in infancy to establish adequate intercirculatory mixing and systemic oxygenation.[1] The arterial switch operation (ASO) has become the gold-standard surgical repair, with excellent long-term survival rates when performed in the neonatal period. However, patients who survive into adolescence without definitive surgical correction or those with delayed diagnosis represent an exceptional clinical scenario.[2]

In these rare cases, the left ventricle (LV) gradually regresses under chronic pulmonary circulation exposure, while the right ventricle (RV) remodels progressively to sustain systemic output over years.[3,4] This chronic hemodynamic adaptation renders the ventricles unsuitable for ASO, as the LV loses contractility and the RV becomes dependent on systemic perfusion. In such circumstances, the Senning procedure a classic atrial switch operation offers a physiologically sound alternative.[4,5] By redirecting venous return at the atrial level via a baffle constructed from the right atrial wall, the procedure converts the parallel circulation back into a series arrangement, restoring effective biventricular physiology and improving long-term outcomes.[4,5]

Anesthetic management of these complex patients demands meticulous hemodynamic control, judicious inotropic support, strict electrolyte optimization, and vigilance against rhythm disturbances. This case report describes the perioperative anesthetic challenges and strategies employed in successfully managing a 13-year-old adolescent with TGA-IVS who underwent elective Senning procedure, highlighting key principles that may benefit anesthesiologists caring for similar complex cardiac populations.[6]

## CASE DESCRIPTION

### *Patient Demographics and Clinical Presentation*

A 13-year-old male, weighing 28 kg (underweight for age), presented to our institution with progressive exertional dyspnea and cyanosis over the preceding 6 months. Baseline oxygen saturation measured 78% on room air, with significant desaturation during minimal physical exertion.

The patient reported exercise intolerance and frequent episodes of syncope, severely limiting his daily activities. Physical examination revealed central cyanosis, clubbing of fingers and toes, and a systolic ejection murmur consistent with congenital heart disease. No prior surgical intervention had been performed.

### *Diagnostic Findings*

Transthoracic echocardiography revealed complete atrioventricular concordance with ventriculo-arterial discordance confirming TGA-IVS. The aorta originated from the morphological right ventricle, while the pulmonary artery originated from the morphological left ventricle. A large interatrial communication (atrial septal defect) was identified as the sole source of intercirculatory mixing. LV function appeared diminished with reduced contractility, while the RV demonstrated compensatory hypertrophy and was hyperdynamic. Cardiac catheterization was performed for hemodynamic assessment and to determine surgical feasibility. RV systolic pressure was measured at >⅔ of systemic pressure, indicating chronic RV pressure loading. The degree of RV remodeling and the reduced LV contractility precluded safe ASO, as an LV unprepared for systemic workload would likely lead to acute decompensation and early graft failure. LV end-diastolic pressure was elevated at 18 mmHg, reflecting impaired ventricular compliance. Saturations in the pulmonary and systemic circulations confirmed the parallel circulation with obligatory right-to-left shunting through the ASD. Given these hemodynamic constraints, the Senning procedure was selected as the only viable surgical option. The procedure would redirect systemic venous return to the LV (via baffle) and pulmonary venous return to the RV, converting the parallel into a series arrangement and allowing the RV to sustain systemic circulation indefinitely.

### *Preoperative Preparation*

Preoperative optimization included correction of severe anemia (hemoglobin 11.2 g/dL) through

transfusion to increase oxygen-carrying capacity. Electrolytes were normalized, and baseline electrocardiography showed normal sinus rhythm without significant arrhythmias. Cardiac medications included low-dose diuretics and oxygen therapy to maintain saturation above 75%. Prophylactic antibiotics were administered 1 hour before surgical incision.

***Intraoperative Anesthetic Management***

*Induction and Monitoring*

Preoxygenation was performed for 5 minutes with 100% oxygen. Anesthesia was induced with fentanyl 2 µg/kg intravenously followed by midazolam 0.1 mg/kg and rocuronium 1.2 mg/kg for rapid sequence intubation. Endotracheal intubation (size 6.0 tube) was achieved without difficulty. Anesthesia was maintained with sevoflurane (0.8–1.2%) and intermittent fentanyl boluses (0.5 µg/kg every 30–45 minutes).

Standard American Society of Anesthesiologists monitoring was established; electrocardiography, pulse oximetry, capnography, non-invasive and invasive blood pressure measurement (via radial artery catheter), central venous pressure via internal jugular vein, and continuous temperature monitoring.

Transesophageal echocardiography (TEE) was inserted after induction to provide continuous hemodynamic assessment and guide intraoperative management. Baseline TEE confirmed the diagnosis and identified the anatomy suitable for baffle placement.

*Hemodynamic Management*

Careful preload titration was maintained throughout the case using central venous pressure monitoring and TEE guidance. Excessive preload was avoided to prevent RV overdistension; target CVP was maintained between 8–12 mmHg. Normocapnia was strictly maintained (end-tidal $CO_2$ 35–40 mmHg) to avoid elevations in pulmonary vascular resistance, which would compromise pulmonary blood flow and systemic oxygenation.

Inotropic support was initiated early with milrinone 0.5 µg/kg/min for its dual benefits of afterload reduction and lusitropy (improved diastolic function). Epinephrine 0.02 µg/kg/min was added to augment systemic perfusion pressure and RV contractility without excessive tachycardia.

Vasopressin was held in reserve but not required. Mean arterial pressure was maintained between 60–75 mmHg to ensure cerebral and coronary perfusion while avoiding excessive afterload.

Electrolyte optimization was meticulous: serum potassium was maintained between 3.8–4.5 mEq/L, ionized calcium between 4.2–5.0 mg/dL, and magnesium >2.0 mg/dL to minimize arrhythmia risk and preserve sinus rhythm. Blood gases were monitored every 30 minutes and corrected promptly. Mild alkalosis was avoided as it increases pulmonary vascular resistance.

*Cardiopulmonary Bypass and Surgical Technique*

Cardiopulmonary bypass was established with

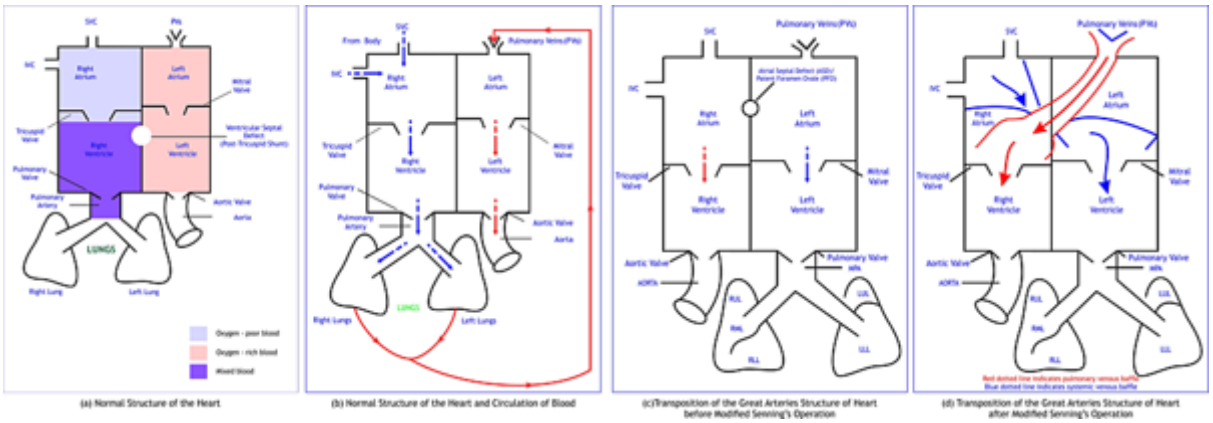

**Figure 1.** Schematic comparison of normal heart, TGA, and circulation after senning procedure[7]

systemic-to-pulmonary artery cannulation. The total CPB time was 120 minutes with an aortic cross-clamp period of 75 minutes. Cardioplegia was administered antegrade at 4°C using a blood cardioplegia solution at 2:1 ratio. The surgical technique involved creation of a baffle from right atrial tissue (autologous pericardium was used as reinforcement in critical areas) to redirect systemic venous return (superior and inferior vena cava) into the left ventricle and pulmonary venous return into the right ventricle.

Hemodynamic instability during weaning from CPB was minimized through aggressive inotropic support: epinephrine was increased to 0.05 µg/kg/min and milrinone maintained at 0.5 µg/kg/min. Moderate hyperoxia ($FiO_2$ 1.0) was continued briefly to lower pulmonary vascular resistance and facilitate RV emptying into the pulmonary circulation.

*Post-Bypass Assessment*

Post-CPB transesophageal echocardiography was invaluable in confirming unobstructed baffles with no evidence of baffle leak or kinking. RV and LV contractility appeared preserved, though mild tricuspid regurgitation was noted deemed acceptable. No significant left ventricular outflow tract obstruction was visualized. The procedure was deemed technically successful.

***Postoperative Course***

The patient was transferred to the pediatric intensive care unit (PICU) on inotropic support and mechanical ventilation. Initial ICU echocardiography revealed systemic RV dysfunction with fractional area change (FAC) of 25% (normal >35%) and tricuspid annular plane systolic excursion (TAPSE) of 7 mm (reduced from normal 16–18 mm in children). Moderate tricuspid regurgitation was present, likely secondary to RV dilatation. Postoperative medications were escalated: milrinone was increased to 0.75 µg/kg/min, nitroglycerin 3 µg/kg/min was added for vasodilation and afterload reduction, and furosemide was administered for mild pulmonary edema noted on chest radiography. Captopril 0.3 mg/kg/dose was initiated to optimize RV loading conditions and reduce regurgitant fraction. Oxygen saturation stabilized above 94% by postoperative hour 8.

The patient tolerated oral intake beginning postoperative day 1. Extubation was successfully achieved at 20 hours post-op, with stable respiratory mechanics and no stridor or airway complications. Sinus rhythm was maintained throughout the ICU stay without necessity for antiarrhythmic therapy. The patient was transferred to the general ward on postoperative day 3 and discharged home on postoperative day 7 with oxygen saturation consistently >95%, excellent exercise tolerance compared to preoperatively, and without any documented arrhythmias.

## DISCUSSION

***Pathophysiology and Surgical Rationale***

Transposition of the great arteries with intact ventricular septum is incompatible with life without intercirculatory mixing.[8] In most cases, survival to adulthood depends on maintenance of a patent foramen ovale or ASD that permits blood to cross between the atria. Without this mixing, the right ventricle pumps deoxygenated blood back to the body (causing cyanosis), while the left ventricle pumps oxygenated blood back to the lungs (causing pulmonary overcirculation and edema if not corrected surgically).[9]

The arterial switch operation has replaced earlier atrial switch procedures (Mustard and Senning) as the definitive surgical management when performed in infancy, with 5-year and 10-year survival rates exceeding 90%. However, in patients presenting late or with prior delays in diagnosis, the chronic hemodynamic burden leads to progressive LV regression and RV remodeling.[3,4] The LV loses contractility as pulmonary vascular resistance remains chronically low, while the RV must maintain systemic pressures indefinitely. By adolescence, the LV is no longer capable of sudden adaptation to systemic workload, rendering ASO inappropriate and dangerous.[4,5]

In such cases, the Senning procedure though an older technique remains a rational surgical option.[4,5] By re-establishing a series circulation via redirection of venous return at the atrial level, the procedure preserves the RV's role in systemic perfusion (which it has been adapted to perform) and allows the LV to recover gradually as pulmonary vascular resistance normalizes. Long-term studies demonstrate improved survival

and reduced arrhythmia burden compared to palliative procedures alone.[10]

***Anesthetic Considerations***

Anesthetic management of patients undergoing atrial switch procedures demands meticulous attention to pulmonary vascular resistance, preload, afterload, and RV contractility. The RV, despite its chronic adaptation, remains susceptible to acute decompensation if afterload is excessive or preload inadequate.[11]

Our choice of milrinone (0.5 µg/kg/min) combined with low-dose epinephrine (0.02 µg/kg/min) reflected the need for simultaneous afterload reduction and inotropy. Milrinone's phosphodiesterase-3 inhibition provides inotropic support without excessive tachycardia or systemic vasoconstriction, while also improving diastolic function a critical benefit in the post-bypass period when the RV is edematous and stiff.[12]

Epinephrine at low doses augments contractility and perfusion pressure without the potent vasoconstriction seen at higher doses. Pure catecholamines or high-dose inotropes would have been counterproductive by increasing systemic vascular resistance and RV afterload.[13]

Strict electrolyte management and avoidance of triggers (hypoxia, hypercarbia, acidosis, hypothermia) were paramount. Atrial switch procedures carry intrinsic arrhythmia risk due to extensive atrial manipulation and suture lines that may serve as reentrant circuits.[4,5]

Our patient maintained sinus rhythm throughout, achieved via meticulous electrolyte optimization and rapid correction of any perturbations. Prophylactic antiarrhythmic agents were not used, as they would have risked additional myocardial depression in an already compromised RV.[14]

Normocapnia, normothermia, and adequate oxygenation were maintained to keep pulmonary vascular resistance low and facilitate pulmonary blood flow. Hyperventilation was avoided despite the temptation to improve oxygenation, as respiratory alkalosis increases Pulmonary Vascular Resistance (PVR). Similarly, hypocarbia from over-ventilation would have impaired RV ejection into the pulmonary circulation, potentially causing RV failure.[15]

Transesophageal Echocardiography (TEE) proved invaluable in real-time assessment of baffle integrity, ventricular function, and the degree of tricuspid regurgitation. It guided inotropic titration and allowed early detection of any technical complications that might have necessitated return to CPB. The ability to visualize unobstructed flow across the baffle and confirm adequate RV and LV contractility provided confidence for successful separation from CPB.[11]

***Postoperative RV Dysfunction Management***

Despite successful repair, the patient demonstrated systemic RV dysfunction in the early postoperative period (FAC 25%, TAPSE 7 mm). This is not uncommon after atrial switch surgery and reflects RV stunning from ischemic injury during CPB, residual elevated afterload, and the inherent limitations of chronic RV remodeling.[16]

Management focused on reducing RV afterload (nitroglycerin, captopril), optimizing contractility (milrinone escalation), and reducing preload with diuretics to alleviate pulmonary edema. The addition of ACE inhibition (captopril) served a dual purpose: afterload reduction and potential long-term myocardial remodeling benefits. These pharmacologic interventions, combined with adequate oxygenation and hemoglobin, permitted recovery of RV function over the first postoperative week, as evidenced by improved systemic oxygenation and exercise tolerance at discharge.[17]

***Clinical Outcome and Long-Term Implications***

Our patient's excellent early postoperative recovery extubation at 20 hours, discharge at day 7 with $SpO_2$ >95% and no arrhythmias demonstrates the feasibility and potential benefits of the Senning procedure in appropriately selected adolescents with TGA-IVS unsuitable for ASO. The dramatic improvement in exercise tolerance and oxygenation compared to the preoperative state reflects the efficacy of re-establishing series circulation.[18]

However, long-term outcomes after atrial switch surgery remain uncertain. Systemic RV dysfunction, tricuspid regurgitation, and arrhythmias (particularly atrial flutter) are

recognized complications that may emerge over years to decades.[4,5] Regular outpatient follow-up with periodic echocardiography and electrocardiography is essential. Some patients require future intervention including valve replacement or catheter-based arrhythmia ablation as the systemic RV gradually deteriorates.[19]

## CONCLUSION

The senning procedure remains a rational surgical option for adolescents with TGA-IVS when the arterial switch operation is no longer anatomically feasible. Successful anesthetic management requires deep understanding of the pathophysiology, judicious selection of inotropic agents (particularly combination therapy with milrinone and low-dose epinephrine), strict control of rhythm and preload, and relentless vigilance against systemic vascular resistance elevation. Intraoperative transesophageal echocardiography is invaluable for confirming baffle integrity and assessing ventricular function.

Dynamic postoperative management with emphasis on afterload reduction, contractile optimization, and electrolyte balance remains essential to address systemic RV dysfunction and minimize arrhythmia risk. Close long-term follow-up to detect and manage late complications is mandatory. Collectively, these challenges underscore the pivotal and multifaceted role of anesthesiologists in caring for this rare and complex population, where detailed perioperative planning and meticulous execution directly translate into improved patient survival and quality of life.

## CONFLICT OF INTEREST

The authors declare no conflict of interest in the writing of this report.

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