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ORIGINAL ARTICLE

# Percutaneous internal jugular venous cannulation for extracorporeal circulation during minimally invasive technique in children with congenital heart disease: operative technique and results

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## ABSTRACT

BACKGROUND: The aim of this study was to evaluate the safety and efficacy of the percutaneous cannulation of the internal jugular venous (PCIJV) for extracorporeal circulation during minimally invasive cardiac surgery (MICS) in children with simple congenital heart disease.

METHODS: From September 2007, 83 children (<16 years) underwent PCIJV for extracorporeal circulation. Primary outcome of the study was to evaluate the safety and advantages of PCIJV technique. Technical steps and pitfalls of PCIJV technique are described.

RESULTS: Median age at surgery was 9 years (range 3.5-16 years) and median body weight was 31 kilograms (range 13-72 kilograms); 32 patients (40%) had a body weight less than 30 kilograms. The PCIJV was achieved with a 14 French cannula in 61 pts (73%), with a 17 Fr cannula in 22 (23%). The PIJVC was judged difficult in 2 patients (2.4%); in both of them cannulation was achieved at a different venous site There were no procedure-related complications and no flow disturbances during the extracorporeal circulation.

CONCLUSIONS: The PCIJV during MICS is an effective and reproducible technique for achieving peripheral CPB in children with simple CHDs. We progressively expanded the use of this technique in smaller children and this allows us to further minimize surgical trauma without experiencing venous drainage's problems.

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Minimally invasive cardiac surgery (MICS) and closed chest cardiopulmonary bypass (CPB) techniques are in continuous evolution.[1-3] Saving vital space in less invasive cardiac surgery is of great importance and the introduction of new materials, together with the use of vacuum-assisted venous drainage (VAVD), have allowed a progressively decreasing in size of venous cannula thus making the use of peripheral bypass applicable in patients with progressive lower body weight.[2-4] The ultrasound-guided percutaneous cannulation of the right internal jugular vein (PCIJV) for establishing peripheral extracorporeal cir-

culation during minimally invasive procedure has been described in adult patients.[5-8] However, only few data are currently available on the applicability and safety and advantages of this technique in children with congenital heart disease.[1-3, 9]

The purpose of this study was to assess the safety and efficacy of ultrasound-guided PCIJV in pediatric patients who underwent MICS for correcting simple congenital heart disease (CHD). Particular care is taken to show in details the technical steps and pitfalls of this technique in children.

## Materials and methods

Clinical Investigation Committee from the University Hospital of Padua approved the review of medical records and hospital data, and the procedures followed were in accordance to the institutional guidelines for retrospective record review and protection of patient confidentiality. The president of the ethic committee of Padua, Professor Anna Chiara Frigo, approved the study protocol n.3251/AO/14 on July 17th 2014. All patients signed consent for participation in the research study.

All pediatric patients (age at surgery ≤16 years) who underwent surgical correction of simple congenital heart disease (CHD) with the aid of peripheral cardio-pulmonary bypass (CPB) at our Institution between January 2007 and June 2014 were included. Our initial selection criteria for the use of PIJVC was a body weight above 30 kilograms, however as we became more confident with this technique we progressively expanded the use of this technique in children with a lower body weight. Peripheral CPB was carried on by PCIJV together with the surgical isolation and cannulation of the femoral artery and vein.

The PCIJV was carried on before preparing the surgical field by one of the senior anesthesiologists operating at the pediatric and congenital cardiac surgery unit at the University of Padua where each year about 300 cardiac surgical procedures are performed. Patient's gender, age at surgery, body weight, body surface area, together with the size of the IJV cannulas utilized and the total CPB time were analyzed. Near infrared spectroscopy (utilizing the INVOS 5100 cerebral oxymeter) was used to continuously monitor any variation of cerebral oxygen saturation during the extracorporeal perfusion (NIRS sensor was positioned on the forehead).

Primary outcome of the study was to evaluate the safety and efficacy of PCIJV technique (reported as failed cannulation requiring the percutaneous cannulation of another venous site) and its advantages during MICS children with congenital heart disease.

Categorical variables are shown as absolute frequency and percentage. Quantitative variables were summarized as median and range. In case quantitative variables are not normally distributed (assessed by Shapiro-Wilk normality Test), comparison among groups was carried out by the Kruskal-Wallis Test. Categorical variables were compared by the $\chi^2$ Test or Fisher's Exact Test as appropriate. All reported p-values are two-sided, and significant level of $\alpha$=0.05 was used. Statistical analysis was performed using SAS software.

### *Description of the technique*

Since 2007 the use of remote CPB by peripheral access entered in our minimally invasive protocol armamentarium for treating patients with CHDs. Due to the need of a right atriotomy in most of them, a bi-caval cannulation was routinely achieved by venous access to the superior cava return through PCIJV and to the inferior vena cava through surgical isolation and cannulation of the right femoral vein.[1, 3] In two cases, where the access to the right IJV was judged difficult (more than 2 failed attempts) we adopted an alternative venous access (contra-lateral IJV or the right subclavian vein). A preliminary 2D-echo of the neck is routinely performed to determine vessel's location, patency and size and their relationship to surrounding structures (Figure 1A, B).[5, 10-14] After the induction of general anesthesia, the patients is positioned in slight Trendelenburg position with the head turned 30°over the left side, in a slight extension. Be-

fore PCIJV, a trans-esophageal (TEE) probe is positioned with the aim of assessing the final position of the cannula at the superior vena cava-right atrial junction site, once inserted (Figure 1C, D).

The PCIJV procedure is than carried-out by using standard sterile techniques. The echo-guided puncture of the IJV can be performed by using either the "out-of-plane technique" (which is our technique of choice), consisting in the position of the ultrasonic beam just perpendicular to the vessel axis, or the "in-plane technique", by positioning the ultrasonic beam along the IJV axis. After IJV puncture, the advancement of the needle along IJV axis is guided by minimal movements ending in the penetration of the anterior wall of the IJV (Figure 2A). Once in the vessel lumen, the guide-wire is carefully advanced under TEE guidance. Subsequently, the progressive dilatation of the IJV percutaneous access is achieved by three consecutive dilators, of increasing diameter, to facilitate the introduction of the venous cannula (Figure 2B-D). After completing the IJV dilatation, the superior venous cannula (DLP venous cannulas, Medtronic, US - which is available in three different sizes, 14 Fr, 17 Fr and 21 Fr) is inserted and positioned, under TEE-echo guidance, about 1 cm above the junction between superior vena cava and right atrium (Figure 1D) and fixed to the skin with a stich (Figure 2, Table I). Patient then are heparinized with

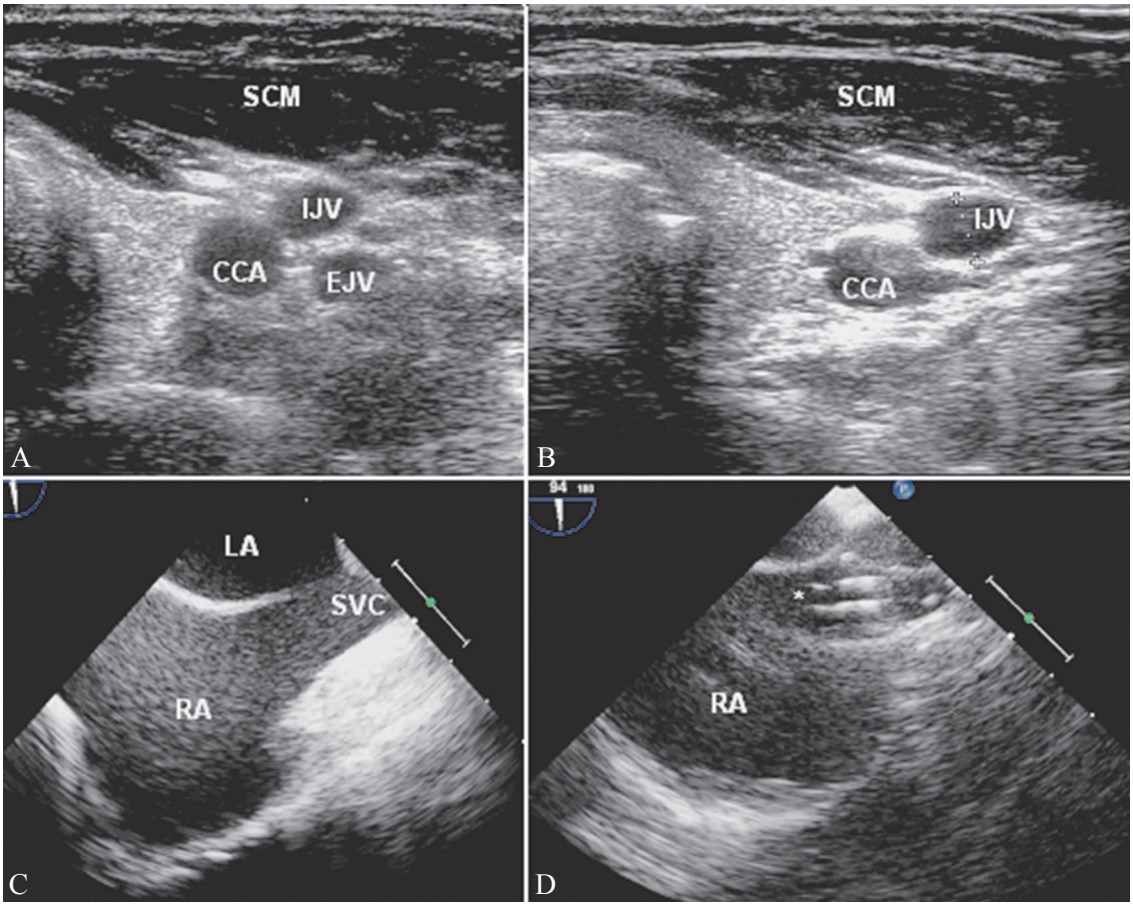


Figure 1.—Operative echo images. A,B) B-mode echo image of the vessels of the neck with linear probe (L 11 Philips, Ultrasound); C, D) 2D-echo mid-esophageal bi-caval view with TEE probe.
CCA: common carotid artery (measured in panel B); EJV: external jugular vein; IJV: internal jugular vein; SCM: sterno-cleidomastoid muscle; IVC: inferior vena cava; LA: left atrium; RA: right atrium; SVC: superior vena cava; panel D *: the cannula for extracorporeal circulation (double contour image) at the SVC-RA junction.

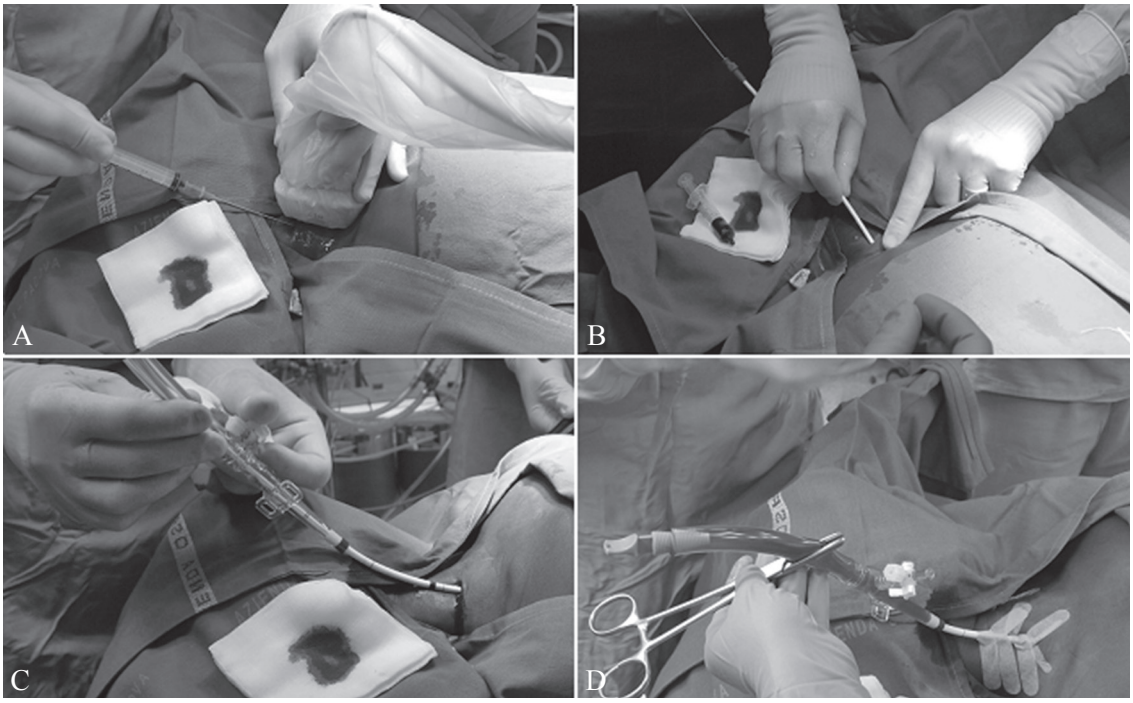


Figure 2.—Operative images of the PCIJV technique in a 4 year-old boy with partial anomalous pulmonary venous connection. A) 2D echo-guided IJV puncture; B) progressive dilation of the IJV insertion site; C) venous cannula insertion; D) venous cannula flushed with heparin solution ready to be connected to the cardio-pulmonary bypass. PCIJV: percutaneous cannulation of the internal jugular vein.

TABLE I.—*Author's suggested size of percutaneous IJV cannula for peripheral cardio-pulmonary bypass according to weight group.*

| IJC cannulas ∅ in French | Weight group kg |
|---|---|
| 14 French | <35 kg |
| 17 French | 35-65 kg |

100 UI/kg of sodium heparin and the cannula is clamped and flushed with heparinized solution to prevent thrombus formation.

The patient is than positioned for surgical access (usually a 30° left lateral decubitus for achieving a right-anterior mini-thoracotomy or more recently a 90° left lateral decubitus for a lateral "axillary" thoracotomy access depending of the congenital heart malformation) (Figure 3). During the maneuver the cannula needs to remain easily accessible by the anesthesiologist to be repositioned under specific surgeons request, after right atrial exclusion by caval snares. This is particularly important in patients with right partial anomalous pulmonary venous return at the superior vena cava-right atrial junction, where the tip of the cannula needs to be positioned far away from the anomalous drainage, in order to favor the following surgical correction.

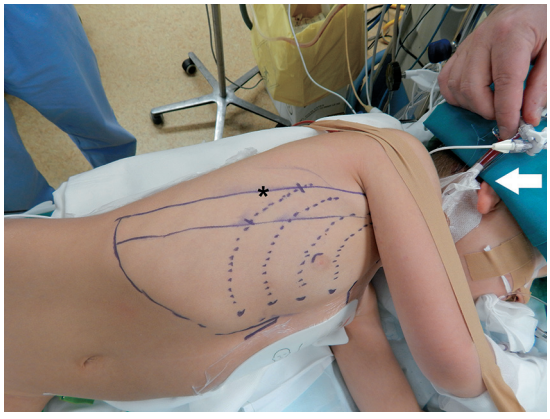


Figure 3.—Intraoperative image showing a 5 year-old boy positioned in left lateral decubitus for a right lateral mini-thoracotomy approach (axillary approach) after the IJV cannula (white arrow) has been positioned. IJV: internal jugular vein.*site of the thoracotomy incision.

Subsequently, addition 200 UI/kg of sodium heparin are given, surgical isolation and cannulation of both femoral artery and vein is performed and the CPB established. The venous drainage is usually implemented by negative pressure (-20 to -40 mmHg, obtained by a centrifugal pump).

At the end of the surgical procedure, following complete heparin antagonization with protamine sulfate, the IJV cannula is removed, usually during chest closure. A gentle compression of the IJV cannulation site is maintained for 10 minutes to promote vessel sealing and a medication is eventually used to close the insertion site.

## Results

One hundred thirty-nine patients underwent minimally invasive cardiac surgical procedures for correction of CHDs with the aid of peripheral CPB in our institution, of which 83 (60%) were children (younger than 16 years of age) that were included in our study. Regarding children, there were 43 males and 40 females; their median age at surgery was 9 years (range 3.5-16 years) and their median body weight was 31 kg (range 13-72 kilograms). Thirty-two patients (40%) had a body weight lower than 30 kilograms. The main diagnoses leading to surgery are listed in listed in Table II.

The PCJVC was achieved by means of a 14 French cannula in 61 pts (74%), a 17 Fr cannula in 22 (23%). There were no complications related to IJV puncture. The right IJV cannulation was not possible in 2 patients (2.4%); in both of them cannulation was achieved at a different venous site (the right subclavian vein in 1 patients and the left IJV in the other patient). None of the patients were turned into a central superior vena cava surgical cannulation.

TABLE II.—*Main diagnosis leading to surgery (N.=83 patients).*

| | N. of patients |
|---|---|
| Atrial septal communication ostium secundum type | 67 |
| Partial anomalous pulmonary venous connection | 11 |
| Ventricular septal defect | 2 |
| Sub-aortic fibro-muscular stenosis | 2 |
| Mitral regurgitation | 1 |

The majority of patients needed to be positioned in an anterior-thoracotomy approach (53 patients, 63%) or left lateral decubitus (30 patients, 36%) (Figure 3).[1, 3, 15, 16] Median CPB time was 49 minutes (range 14-228 minutes) and we did not experience any flow disturbances during the extracorporeal perfusion. The IJV cannula needed to be repositioned during the procedure in 18 patients (21%), due to a higher anomalous drainage of one pulmonary vein into the superior vena cava (N.=12) or to favor caval snaring before right atriotomy (N.=6). We did not have significant decreased values, as respect to the baseline, at cerebral NIRS monitoring during the cardiopulmonary bypass (median baseline value of 77, range 74-85 versus a median value during extracorporeal perfusion of 81, range 76-88, P=ns). There were no complications related to the removal of the venous cannula such as perivascular hematomas or prolonged bleeding at the insertion site.

## Discussion

Minimally invasive surgical techniques in pediatric cardiac surgery are evolving, along with the introduction of new surgical techniques and innovative materials.[1] A right mini-thoracotomy, a mid-line mini-sternotomy and a newly introduced lateral mini-thoracotomy ("axillary approach") are surgical techniques that are routinely employed in our Institution.[1, 3, 15, 16] During the last decade there is an increasing use of the remote CPB by peripheral vessel cannulation during MICS, mainly in adult patients requiring surgery on the mitral valve.[2, 4] More recently the application of remote CPB has been extended to pediatric patients requiring MICS for their CHDs.[1-3, 9] Since in the majority of patients the correction of CHD requires a right atrial access, a bi-caval cannulation is mandatory to achieve an adequate venous drainage during right atrial exclusion.[6] In these patients, the superior caval venous return to the extra-

corporeal circulation is ensured by an echo guided PCIJV and an inferior caval return through the surgical isolation and cannulation of the right femoral vein. It is well known that central venous access in children is more difficult than in adult.[12, 14] Investigations focusing on this topic have found many reasons to these difficulties. First, the small dimension of the IJV in infants and infants (which is correlated to age and body surface area) makes this access more difficult than in adults.[17, 18] Second, many ultrasound studies have found variations in internal jugular position relative to the common carotid artery, with the internal jugular vein being anterior to the carotid artery in many cases.[14, 18] Echo-guided venous access has the advantage of leading and facilitating the puncture of the vessel thus reducing the risk of complications.[14, 18] In fact, the occurrence of a peri-vascular hematoma, as a consequence of multiple attempts of vessel puncture or direct puncture of the carotid artery, is the most frequent complication during cannulation of the right IJV, which will make its access more difficult even when ultrasound localization is used as a rescue technique.[17, 18] In addition, the echo guided venous access have the advantage of displaying the correct position of the guide-wire in the vessel lumen before using the introducers for vessel dilatation, thus further reducing potential vascular complications.[5]

According to our results we were able to utilize the peripheral CPB in 83 pediatric patients, 32 of them with a body weight less than 30 kg. The echo-guided right PCIJV was possible in the vast majority of patients (81/83, 98%). In cases of failed right IJV cannulation, it was possible to obtain a different percutaneous echo-guided venous access to get the superior vena cava drainage. None of the patients were turned into a central superior vena cava surgical cannulation. We did not experience any problems with unsatisfactory venous drainage and the IJV cannula was easily accessible during the surgery and was easily repositioned by the anesthesiologist (usually slight retrieved) according to surgeon's request when needed.

*Limitations*

This study has a few limitations. First of all, this is a retrospective data examination and the population of our patients who underwent MICS with the aid of peripheral CPB is small and does not allow us to reach definitive conclusions. In addition a certain operative variability can be present within our cardiac-anesthesiology staff.

Nonetheless, the use the echo-guided PCIJV becomes nowadays a standard technique in our Unit. The utilization of this technique has been progressively extended in even smaller children since when we started to use this technique and this allowed us to further refine and extend the applicability of our minimally invasive approaches for the correction of simple CHD.

## Conclusions

In conclusion, the PCIJV during MICS is an effective and reproducible technique for achieving remote CPB in children with simple CHDs. It can be done safely in smaller children (above 13 kilograms of body weight) and in patients requiring left lateral decubitus (for "axillary approach") without experiencing venous drainage's problems. The constant and strict cooperation between pediatric cardiac anesthesiologist and surgeons in the operating room proves effective during the last a few years in expanding the use PIJVC during MICS for the treatment of CHD in pediatric patients in our Unit.

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