

giography revealed diminished or absent perfusion of the entire left lung and the lower two lobes of the right lung. Right ventricular systolic pressure was 75 torr and arterial blood pressure was 60/40 torr. Estimated time from embolization to the commencement of operation was 5 hours. The anesthesia circuit employed was a standard jumbo adult circle absorption system using transparent unidirectional dome valves.

Interposed between both absorber mounted valves and the conductive rubber corrugated hoses were opaque conductive bacterial filters.†

Induction and maintenance of anesthesia and extracorporeal perfusion were initially uneventful. Prior to bypass, pulmonary compliance was adequate and no problem with ventilation was evident.

Following closure of the pulmonary arteriotomy and the reestablishment of partial bypass, copious amounts of grossly hemorrhagic pulmonary edema fluid were seen. Within the first few minutes of partial bypass, several hundred milliliters of this fluid were suctioned from the endotracheal tube. During this period, "pulmonary" compliance rapidly worsened. A pressure of 50 cm H₂O was necessary for inflation of the lungs, and emptying was extremely slow. Finally, gas trapping appeared complete. It was then noticed that when the circuit was disconnected for suctioning, the lungs rapidly emptied. A mechanical obstruction to exhalation was sought. The expiratory dome valve was dry and seemed functional. The corrugated tubing was drained of about 20–30 ml of frothy fluid, but obstruction persisted. Removal of the bacterial filter on the expiratory limb immediately restored the normal function of the system.

† Ohio Medical Products, Catalog #225-2615-700.

DISCUSSION

The disposable filters used in this case normally have a very low resistance to air flow (less than 1 cm H₂O at 501 pm). The manufacturer states that the filter material is hydrophobic and that exposure to air fully saturated with water vapor at 37 C for ten hours does not materially increase airway resistance. However, if the filter is suddenly flooded with fluid and positive airway pressure applied to the filter from the same side, complete occlusion occurs. Positive pressure applied from the opposite side clears the filter and restores patency.

In the case described, pulmonary edema fluid traveled down the exhalation limb of the breathing circuit and was forced into the filter pores by positive pressure. The inspiratory filter remained functional, since any fluid which did manage to reach it was expelled by gas flow in the opposite direction.

The current practice in our department is now to filter routinely only the inspiratory limb of the anesthesia breathing circuit. We do not hesitate to add an expiratory filter when faced with a patient who has active infectious pulmonary disease. However, we strongly discourage the use of such a filter in patients subject to either pulmonary hemorrhage or edema.

Percutaneous Catheterization of the Internal Jugular Vein in Infants and Children

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During the past two decades, central venous pressure (CVP) monitoring has become recognized as a valuable tool in the care of critically ill patients. The use of the internal jugular

approach in adult patients has recently gained widespread popularity because of its low incidence of complications. The assurance of placing a central venous pressure catheter into the superior vena cava or right atrium makes internal jugular catheterization a very desirable technique. English and colleagues reported a success rate of 91 per cent in a group of 85 infants and children in whom cannulation of the right or left internal jugular vein was attempted, and a success rate of 96 per cent in a group of 415 adult patients undergoing the same procedure.¹ Despite this report, popularization of the use of this tech-

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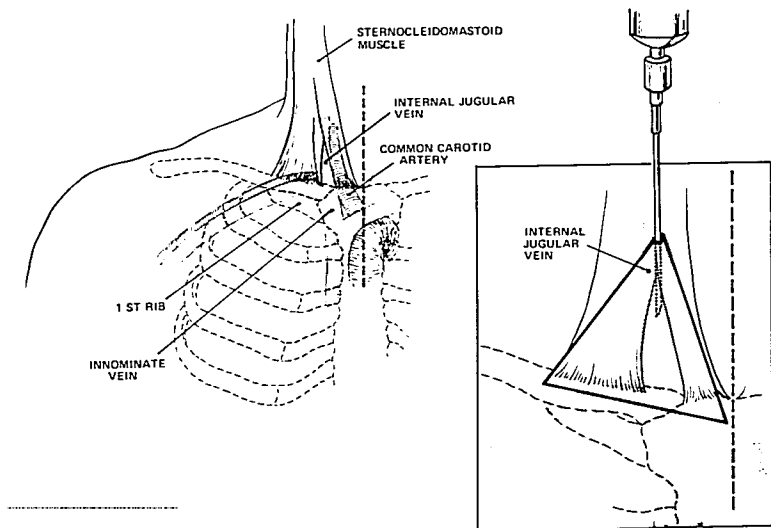


FIG. 1. Diagram of the landmarks used to locate the internal jugular vein. The internal jugular vein lies just behind the sternocleidomastoid muscle within the center of the triangle in (B). The common carotid artery is in a posterior (deeper) and medial position in relation to the internal jugular vein.

nique in the pediatric age group has proceeded slowly because of difficulties anticipated in the safe, accurate placement of catheters.

To validate the work of English, a prospective evaluation of percutaneous internal jugular venous catheterization and its possible complications in a group of infants and children undergoing cardiovascular surgery was performed at our institution.

METHODS AND MATERIALS

Fifty-two patients ranging in age from 6 weeks to 14 years were studied. The technique employed was similar to that of Daily,² the only differences being a more acute angle of the needle with the skin and a more cephalad entry of the needle. After general anesthesia was established and endotracheal intubation accomplished, the patient was placed in a 15–20-degree Trendelenburg position with the head turned to the contralateral side of the

anticipated venipuncture. A roll of toweling was placed under the shoulders to allow hyperextension of the neck, thus bringing the vascular structures of consequence into a more favorable position. The catheterization was performed by anesthesia residents familiar with the technique of internal jugular vein catheterization in adults and under the supervision of a staff anesthesiologist.

The anatomic landmarks were identified: the sternal and clavicular segments of the sternocleidomastoid muscle and the clavicle form a triangle slightly medial and posterior to the internal jugular vein (fig. 1).

Because of direct access to the right atrium, the right side was attempted first. The neck was prepared with an antiseptic solution, then a 20- or 21-gauge needle attached to a 10-ml syringe was used to locate the position of the vessel. The needle was inserted at the apex of the triangle at a 45-degree angle with the skin and directed caudad and laterally toward the

TABLE 1. Location of Catheter Tip by X-ray

A. Right internal jugular catheterization*		
Right atrium	25	} 30
Superior vena cava	5	
B. Left internal jugular catheterization		
Right atrium	5	} 9
Superior vena cava	3	
Subclavian vein	1	
C. External jugular catheterization		
Right atrium	3	} 9
Superior vena cava	3	
Subclavian vein	2	
Axillary vein	1	
	Total	48/52

* One patient died intraoperatively and was excluded from the study.

ipsilateral nipple. The vessel was usually entered within 1-2 cm of the skin surface. After noting its depth and direction, the small needle was removed.

The internal jugular vein was then entered with a medium-sized 8-inch Intracath introducer needle attached to a 10-ml syringe. During insertion of the Intracath needle, continuous negative pressure was maintained with the syringe. When the vein was entered, as often indicated by a characteristic loss of resistance or "pop" through the vessel wall and free return of venous blood, the syringe was removed and the catheter threaded through the introducer needle. If difficulty in advancing the catheter was encountered, the needle and catheter were removed together, thus avoiding the possibility of shearing off the catheter. Once the catheter tip was felt to be in a satisfactory position, the intravenous fluid bottle was lowered below the level of the heart in order to observe retrograde flow of blood, thus confirming the catheter's function as well as the position of the catheter tip.

If the attempt was unsuccessful on the right side, catheterization of the left internal jugular was attempted, keeping in mind that the apex of the pleura is higher on the left. Failing successful venipuncture on the left, cannulation of an external jugular vein was attempted.

The catheters were then sutured in place with #4-0 nylon suture to secure their

placement for the duration of the operative procedure and for the postoperative phase. Following operation, a roentgenogram of the chest was taken to check the placement of the catheter tip. The patients were checked periodically throughout the duration of catheterization for evidence of infection or other complications.

RESULTS

Successful catheterization of the right or left internal jugular vein was achieved in 40 of 52 patients. In 31 patients the right internal jugular vein was catheterized. In nine patients it was necessary to cannulate the left internal jugular vein. The overall success rate in cannulating the right or left internal jugular vein was 77 per cent. Of the remaining 12 patients in whom internal jugular catheterization was not successful, central venous pressure measurement was obtained by cannulation of the right or the left external jugular vein (9 patients) or by saphenous vein cutdown (3 patients).

Roentgenographic examination showed that the tips of all central venous lines inserted percutaneously via the right internal jugular vein rested within the right atrium or the superior vena cava (table 1). Eight of nine catheters inserted through the left internal jugular vein also reached the right atrium or superior vena cava; one catheter was located in the left subclavian vein. Of nine external jugular catheterizations, six were located in the superior vena cava or right atrium. In two patients the catheter tip was within the subclavian vein, one of these having passed to the contralateral side. A third malpositioned catheter from an external jugular vein passed distally into an axillary vein.

In order to evaluate other factors influencing successful percutaneous catheterization of the internal jugular vein, the age, the weight and the initial central venous pressure of each patient was tabulated. Success and failure groups were compared. It was presumed that our experience would demonstrate more difficulty in satisfactory cannulation of the internal jugular vein in infants (table 2). The rate of successful cannulation in this group (6 weeks-24

months) was less than that in the 2-14-year-old age group (table 2).

Success of catheterization did not seem to relate to body weight, although the success rate was somewhat higher in infants weighing more than 10 kg compared with infants weighing less than 10 kg (table 3). The rate of successful catheterization was somewhat higher in children when CVP was greater than 10 cm H₂O (table 4). In each of these three comparisons, chi-square analysis indicated a difference that was not significant at the .05 level.

The only complications noted were hematoma formation in three of 12 patients in whom a carotid artery was punctured and two cases of Horner's syndrome. We attributed the low rate of hematoma formation to the use of a small-gauge "locating" needle and the prompt application of pressure when an arterial vessel was punctured. Both patients who developed Horner's syndrome recovered completely.

DISCUSSION

Internal jugular venipuncture is a more difficult technical procedure in infants than in older children. The anatomic landmarks are less apparent and there is more difficulty in threading the catheter once the vein is entered. It is our impression that the greater the familiarity with the procedure, the easier its application in children. The report by English lends credence to this statement, as he demonstrated a higher rate of success once experience with the technique was achieved. An increase in rate of success with greater experience may also explain the difference in results between our group of infants and children (77 per cent success in 52 patients) and English's group (91 per cent success in 85 patients), a difference significant at $P < 0.05$.

Other means of central venous pressure monitoring have particular disadvantages. The use of the subclavian vein was popularized following a report in 1962 by Wilson.³ Its careful application in adults resulted in few but significant complications. However, one need only read the recent report by Groff and Ahmed⁴ to conclude that its use in the

TABLE 2. Percutaneous Internal Jugular Catheterization (Right and Left), Success by Age

Age Group	Right	Left	Total	Per Cent Success
6 weeks-2 years	9	4	13/19	68
2 years-14 years	22	5	27/33	82
TOTAL	31	9	40/52	77

TABLE 3. Percutaneous Internal Jugular Catheterization (Right and Left), Success According to Weight

<10 kg	14/19	74 per cent
>10 kg	26/33	79 per cent

TABLE 4. Percutaneous Internal Jugular Catheterization (Right and Left), Success by CVP

<10 cm H ₂ O	21/29	72 per cent
>10 cm H ₂ O	19/21	90 per cent

pediatric age group can only be condemned. In 44 patients less than 2 years old, there were five major complications, including two deaths, attributed to subclavian vein catheterization.

Of the significant complications here reported, the hematomas were not of consequence. Horner's syndrome following internal jugular catheterization has been reported.⁵ We believe this phenomenon to be secondary to either direct injury to the sympathetic chain or localized tissue edema with or without hematoma formation; in view of the complete resolution in both cases, the latter hypothesis is more likely. Strict care must be taken, however, to avoid the prevertebral area in which the sympathetic chain rests. No case of pneumothorax or infection was observed.

Finally, we strongly encourage the use of a small-gauge needle to locate the internal jugular vein. This should lead to more accurate intrajugular placement of the Intracath unit with its large-bore needle, thus avoiding serious complications that could result from unnecessary probing.

In summary, percutaneous catheterization of the internal jugular vein in children for

central venous pressure monitoring has several advantages: the technique is simple; direct placement of the catheter tip into the right atrium or the superior vena cava is virtually assured; accurate central venous pressure measurements are then available; and there are few serious complications. Further evaluation of this technique appears to be indicated.

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Ethylene Oxide Degassing of Rubber and Plastic Materials

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The availability of safe, convenient, inexpensive methods of "cold" sterilization has allowed development of sterile disposable anesthesia equipment. It has also made possible re-sterilization of bulky or heat-sensitive inhalation therapy and anesthesia equipment. Sterile equipment prevents nosocomial infection.¹ The clinical value of sterile disposable endotracheal tubes is known.² Dryden has encouraged use of "clean" disposable anesthesia circuits and sterilization of equipment such as blood pressure cuffs.^{3,4} The problems of hospital sterility control have been described.⁵⁻⁷

Ethylene oxide (EO) sterilization is the method usually used for articles that might be injured by autoclaving. Ethylene oxide will flow over and around all surfaces and can be used to sterilize metal products. In contrast, with gamma irradiation there is attenuation of particles as metals are penetrated, and this may prevent total steriliza-

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tion of hollow products even when rotated. Anesthesiologists, led by the Buffalo General Hospital group⁸ and John Snow of Boston,⁹ have used EO sterilization for more than 15 years. Recent reviews¹⁰⁻¹² confirm continued interest.

ETHYLENE OXIDE RESIDUALS

Ethylene oxide is sorbed by rubber and plastic,¹³ as it is but slightly polar. EO adsorbs

ABBREVIATIONS

- RH = relative humidity
ppm = parts per million
EO = ethylene oxide
Blue Portex = Portex Blue-line 3.5-mm endotracheal tube
Leyland = red rubber Leyland 3.5-mm endotracheal tube
Oxford = Leyland Oxford style 3.5-mm pediatric endotracheal tube
Red Bardex = Bardex 8 French female Foley catheter (rubber)
Yellow Bardex = Bardex 8 French male Foley catheters (latex)

GENERIC EQUIVALENTS

- Freon 11 is trichloromonofluoromethane
Freon 12 is dichlorodifluoromethane
Freon 11 is the same as UCON 11
Freon 12 is the same as UCON 12

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