Anesthesiology
2000; 93:319–24

Competence of the Internal Jugular Vein Valve Is Damaged by Cannulation and Catheterization of the Internal Jugular Vein

Xianren Wu, M.D., Wolfgang Studer, M.D.,† Thomas Erb, M.D.,† Karl Skarvan, M.D.,‡ Manfred D. Seeberger, M.D.§*

Background: **Experimental results suggest that the competence of the internal jugular vein (IJV) valve may be damaged when the IJV is cannulated for insertion of a central venous catheter. It has further been hypothesized that the risk of causing incompetence of the proximally located valve might be reduced by using a more distal site for venous cannulation. The present study evaluated these hypotheses in surgical patients.**

Methods: **Ninety-one patients without preexisting incompetence of the IJV valve were randomly assigned to undergo distal or proximal IJV cannulation (≥ 1 cm above or below the cricoid level, respectively). Color Doppler ultrasound was used to study whether new valvular incompetence was present during Valsalva maneuvers after insertion of a central venous catheter, immediately after removal of the catheter, and, in a subset of patients, several months after catheter removal, when compared with baseline findings before cannulation of the IJV.**

Results: **Incompetence of the IJV valve was frequently induced both by proximal and distal cannulation and catheterization of the IJV. Its incidence was higher after proximal than after distal cannulation (76%** ***vs.*** **41%; $P < 0.01$) and tended to be so after removal of the catheter (47%** ***vs.*** **28%; $P = 0.07$). Valvular incompetence persisting immediately after removal of the catheter did not recover within 8–27 months in most cases.**

Conclusions: **Cannulation and catheterization of the IJV may cause persistent incompetence of the IJV valve. Choosing a more distal site for venous cannulation may slightly lower the risk of causing valvular incompetence but does not reliably avoid it. (Key words: Central venous catheter; color Doppler; complication; intracerebral venous blood pressure.)**

IN approximately 90% of human internal jugular veins (IJVs) there is a valve.[1,2] It is situated directly above the termination of the IJV in the inferior bulb, the position of which may vary slightly from being almost directly posterior to the head of the clavicle to a position 3 cm further inferior and 3 cm further lateral.[3] The valve prevents backward blood flow toward the brain when the intrathoracic pressure acutely increases and can create transvalvular gradients of up to 100 mmHg.[3] The competence of the valve has been found to be crucial for developing a transcranial blood pressure gradient during cardiopulmonary resuscitation with closed-chest compression.[4] In addition, this valve prevents sudden increases in the IJV pressure during coughing or positive-pressure ventilation and may thus protect the brain from acute increases in intrathoracic pressure.[3,5]

Imai *et al.*[5] reported in a preclinical study that competent IJV valves became incompetent after being intentionally punctured with a 14-gauge needle. Because the IJV valve may be situated slightly above the clavicle at the base of the neck,[3] they raised the concern that it may be injured in clinical situations when the IJV is cannulated at the lower neck for insertion of a central venous catheter.[5] To decrease the risk of direct puncture of the proximally located valve, they recommended using a more distal site for cannulation of the IJV, *i.e.*, at the level of thyroid cartilage.[5] We note that even if the valve is not directly punctured, the fragile IJV valve can be structurally damaged by interference with a central venous catheter, as found by an autopsy study,[1] and might thus become incompetent. The clinical relevance of these experimental and autopsy findings is unclear. Therefore, the present Doppler ultrasound study was designed to evaluate in patients whether incompetence of the IJV valve is induced by cannulation and catheterization of

* Research Fellow.

† Assistant Professor.

‡ Professor.

§ Associate Professor.

Received from the Department of Anesthesia and Research, University of Basel/Kantonsspital, Basel, Switzerland. Submitted for publication September 8, 1999. Accepted for publication January 24, 2000. Supported in part by the Swiss Society of Anaesthesiology and Reanimation, Berne, Switzerland. Presented in part at the annual meeting of the American Society of Anesthesiologists, San Diego, California, October 18–22, 1997.

Address reprint requests to Dr. Seeberger: Department of Anesthesia, University of Basel/Kantonsspital, CH-4031 Basel, Switzerland. Address electronic mail to: mseeberger@uhbs.ch

the IJV. In addition, the study evaluated whether any induced valvular incompetence was related to the site used for cannulation of the IJV.

Patients and Methods

Patient Population

After obtaining institutional approval and patients' written informed consent, 126 patients who had not undergone previous IJV cannulation and who were scheduled for elective cardiac surgery were recruited for the study. These patients routinely receive a central venous catheter inserted through the right IJV as part of their clinical care at our institution. Thirty of these patients (24%) were later excluded from the study because of preexisting incompetence of the IJV valve. Another five patients were excluded because of failure in right IJV catheterization (n = 2), poor ultrasonographic quality (n = 2), or poor postoperative outcome (n = 1).

After induction of anesthesia, the patients were placed supine in a 15° Trendelenberg position with their heads slightly (< 40°) rotated to the left from the midline.[6] A table of random numbers was used to allocate patients to either distal cannulation of the IJV, *i.e.*, ≥ 1 cm above the cricoid cartilage (distal cannulation group, 46 patients) or proximal cannulation, *i.e.*, ≥ 1 cm below the cricoid cartilage (proximal cannulation group, 45 patients). Given the previously described anatomy,[3] distal cannulation was expected to result in puncture of the IJV clearly outside of the location of the IJV valve, whereas proximal cannulation (at the base of the neck) was expected to potentially result in puncture of the IJV in the area where the IJV valve is located. Customary anatomic landmarks[6] and a 22-gauge finder needle were used to identify the IJV either distally or proximally. The IJV was then cannulated with an 18-gauge needle, and the Seldinger technique was used for insertion of a 7-French triple-lumen catheter (Arrow-Howes multilumen central venous catheterization set; Arrow International Inc., Reading, PA).

Experimental Protocol

Two-dimensional and color Doppler ultrasound examinations (HP Sonos 2500 with 5-MHz probe; Hewlett Packard, Andover, MA) of blood flow through the IJV valve were performed preoperatively before induction of anesthesia and subsequent cannulation of the IJV (baseline, T1), 3–4 days after the surgery immediately before the catheter was removed (T2), and immediately after removal of the catheter (T3). In patients with marked incompetence of the IJV valve persisting after removal of the catheter, a follow-up study was performed within 8–27 months (median, 19 months) after removal of the catheter (T4).

Ultrasound studies that were recorded on S-VHS tape were always performed according to the following method. With the patient lying supine, the short- and long-axis views of the right IJV were imaged, and the valve was identified. The area of IJV in the short-axis view was measured immediately distal to the valve during spontaneous breathing at end expiration and during a Valsalva maneuver. The blood flow through the IJV valve was then imaged in the long-axis view by using color Doppler ultrasound, and the competence of the IJV valve was assessed during Valsalva maneuvers. To standardize the Valsalva maneuvers, patients were asked to acutely blow against a manometer and create an airway pressure of 40 mmHg for ≥ 5 s. Color Doppler findings of the blood flow during the Valsalva maneuvers were digitally acquired and stored on an optical disc for evaluation.

Evaluation of the Competence of the Internal Jugular Vein Valve

Color Doppler findings at T1, T2, T3, and T4 (when available) were digitized to allow side-by-side presentation of the findings of each patient on one screen. These randomly displayed findings were evaluated independently by two readers who were unaware of the site of venous cannulation. A semiquantitative scale from 0 to 4 that considered duration and size of backward blood flow through the IJV valve during Valsalva maneuvers was used for evaluation of valvular competence. Grade 0 was defined as no backward blood flow; grade 1 was defined as a short (< 1.0 cm) regurgitant jet with a width < one third of the IJV diameter and duration < 0.2 s; grade 2 was defined as a short (< 1.0 cm) regurgitant jet with a width < one third of the IJV diameter and duration 0.2–0.4 s; grade 3 was defined as a regurgitant jet with a width between one third and two thirds of the IJV diameter or duration > 0.4 s; and grade 4 was defined as a regurgitant jet with width > two thirds of the IJV diameter. The ratio of the width of the color jet to the diameter of the IJV was measured close to the origin of the jet. Based on these readings, diagnosis of induced valvular incompetence was made if regurgitation grades increased by more than one grade at T2, T3, and T4 compared with the baseline finding at T1.

To test the reproducibility of the readings, interob-

Table 1. Incidence of Induced Incompetence of the Internal Jugular Vein Valve and Cross-sectional Area of the Internal Jugular Vein in 46 Patients with Distal Internal Jugular Vein Cannulation and 45 Patients with Proximal Cannulation

	Baseline (Preop; T1)	With Catheter (Postop; T2)	Catheter Removed (Postop; T3)
Incompetence*			
Distal	—	19 (41)†	13 (28)
Proximal	—	34 (76)†‡	21 (47)‡
$Area_{IJV}$, end expiration (cm^2)			
Distal	1.3 ± 0.6	1.9 ± 1.1§	2.0 ± 1.1§
Proximal	1.2 ± 0.6	1.8 ± 0.8§	1.9 ± 0.8§
$Area_{IJV}$, Valsalva (cm^2)			
Distal	1.9 ± 0.9	2.4 ± 1.2§	2.4 ± 1.4§
Proximal	1.9 ± 0.8	2.1 ± 0.9	2.1 ± 0.9

Data are number of patients (%) or mean ± SD.

* Based on a semiquantitative five-grade scale, diagnosis of induced valvular incompetence was made if regurgitation grades during Valsalva maneuver increased by > 1 grade at T2 and T3 compared with the baseline finding at T1.

† The incidence of valvular incompetence in the proximal cannulation group was significantly greater than in the distal cannulation group ($P < 0.01$).

‡ The incidence of valvular incompetence in the proximal cannulation group was significantly smaller after removal of the catheter than with catheter in place (P 0.01).

§ $Area_{IJV}$ significantly larger than at baseline ($P < 0.01$).

IJV = internal jugular vein; Preop = preoperative study; Postop = postoperative study.

server and intraobserver variability was assessed using the κ coefficient. Assessment of interobserver variability was based on agreement or disagreement regarding presence or absence of a difference in the regurgitation scores between baseline and T2, T3, and T4 findings. Intraobserver variability was assessed analogously after repeated readings of 25% of the findings. A consensus reading was performed for controversial readings.

Statistical Analysis

The chi-square test was used to compare the frequency of valvular incompetence. A repeated-measures analysis of variance followed by Bonferroni multiple comparisons test or Student *t* test were used to analyze the differences in the area of the IJV between different study points and between the two groups (InStat version 2.02, GraphPad Software Inc., San Diego, CA). Continuous variables are reported as mean values ± SD.

Results

The two groups were similar regarding gender and age. In the distal cannulation group, there were 37 men and 9 women with a mean age of 59 ± 11 yr; in the proximal cannulation group, there were 35 men and 10 women with a mean age of 61 ± 11 yr.

Table 2. Regurgitation of Blood Flow through the Internal Jugular Vein Valve: Distribution of Patients in a Semiquantitative Five-grade Scale

	Distal Cannulation Group (n = 46)			Proximal Cannulation Group (n = 45)		
Grade*	Baseline (Preop; T1)	With Catheter (Postop; T2)	Catheter Removed (Postop; T3)	Baseline (Preop; T1)	With Catheter (Postop; T2)	Catheter Removed (Postop; T3)
0	34	9	22	30	5	11
1	9	12	10	12	5	8
2	3	10	5	3	8	12
3	0	10	4	0	14	6
4	0	5	5	0	13	8

Data are number of patients. Based on these raw data, diagnosis of induced valvular incompetence was made if a > 1-grade increase in regurgitation occurred after insertion of a central venous catheter into the internal jugular vein compared with the preoperative baseline finding.

* Grade 0 on the semiquantitative five-grade scale represents no regurgitation of blood flow through the internal jugular vein valve during a Valsalva maneuver, grade 5 maximal regurgitant flow (as defined in detail in Patients and Methods).

Preop = preoperative study; Postop = postoperative study.

Table 3. Incidence of Induced Incompetence of the Internal Jugular Vein Valve and Cross-sectional Area of the Internal Jugular Vein in 18 Patients with Valvular Incompetence after Removal of the Catheter and Follow-up after 8–27 Months

	Baseline (Preop; T1)	With Catheter (Postop; T2)	Catheter Removed (Postop; T3)	Follow-up (Postop; T4)
IJV valve incompetence*	—	18 (100)	18 (100)	15 (83)
$Area_{IJV}$ (cm^2), end expiration	1.2 ± 0.7	1.8 ± 0.8†	1.8 ± 0.8†	1.4 ± 0.8‡
$Area_{IJV}$ (cm^2) Valsalva	1.8 ± 1.0	2.2 ± 0.9	2.1 ± 0.9	2.0 ± 0.8

Data are number of patients (%) or mean ± SD.

* Based on a semiquantitative five-grade scale, diagnosis of induced valvular incompetence was made if regurgitation grades during Valsalva maneuvers increased by > 1 grade at T2, T3, and T4, compared with the baseline finding at T1.

† $Area_{IJV}$ significantly larger than at baseline ($P < 0.01$).

‡ $Area_{IJV}$ significantly smaller than at T3 ($P < 0.05$).

IJV = internal jugular vein; Preop = preoperative study; Postop = postoperative study.

Competence of the Internal Jugular Vein Valves during Valsalva Maneuvers

Incompetence of the IJV valve was frequently induced both after proximal and distal cannulation and catheterization of the IJV (table 1). Table 2 gives the detailed raw data of the readings in a semiquantitative five-grade scale on which the diagnosis of induced incompetence was based. After catheterization at T2, its incidence was significantly higher in the proximal group than in the distal group. Immediately after removal of the catheter (T3), the difference between the two groups failed to reach statistical significance ($P = 0.07$).

Area of the Internal Jugular Vein in the Short-axis View

In both groups, the area of IJV at end expiration was significantly larger at T2 and T3 than at T1 (table 1). During Valsalva maneuvers, these increases were less prominent and failed to reach statistical significance in the proximal cannulation group.

Follow-up Study in Patients Whose Internal Jugular Vein Valve Was Incompetent after Removal of Catheter

Of 24 patients who had persisting valvular incompetence more than grade 2 immediately after removal of the catheter (T3), 18 (12 from the proximal group and 6 from the distal group) were available for follow-up study (T4). None of these patients underwent any further surgical intervention or IJV cannulation between T3 and T4. Persisting incompetence of the IJV valve at T4 with grades more than 2 were found in 10 of 12 patients in the proximal group and in 5 of 6 patients in the distal group (table 3; table 4 gives the raw data of the readings). The cross-sectional area of the IJV at end expiration was significantly smaller at T4 than immediately after removal of the catheter (T3) and was only insignificantly larger than at baseline (T1). During Valsalva maneuvers, the area slightly increased from T1 to T2 and T3 and slightly decreased from T3 to T4; however, none of these changes reached statistical significance.

Table 4. Regurgitation of Blood Flow through the Internal Jugular Vein Valve in 18 Patients with Valvular Incompetence after Removal of the Catheter and Follow-up after 8–27 Months: Distribution in a Semiquantitative Five-grade Scale (Raw Data)

Grade*	Baseline (Preop; T1)	With Catheter (Postop; T2)	Catheter Removed (Postop; T3)	Follow-up (Late Postop; T4)
0	6	0	0	0
1	9	0	0	0
2	3	4	2†	3
3	0	6	7	4
4	0	8	9	11

Data are number of patients.

* Grade 0 on the semiquantitative five-grade scale represents no regurgitation of blood flow through the internal jugular vein valve during a Valsalva maneuver, grade 5 maximal regurgitant flow (as defined in detail in Patients and Methods).

† The initial reading had resulted in grade 3 in both of these patients, whereas the second reading after completion of the follow-up study resulted in a consensus-based diagnosis of grade 2 (after one reader had diagnosed grade 3 and the other reader grade 2).

Preop = preoperative study; Postop = postoperative study.

Interobserver and Intraobserver Agreement

The κ coefficient for interobserver agreement regarding presence or absence of a difference in the regurgitation scores between baseline and the following study points was 0.81; κ for intraobserver agreement of repeated readings was 0.81 and 0.91.

Discussion

Our study shows that cannulation and catheterization of the IJV frequently causes incompetence of the IJV valve, and that valvular incompetence persisting after removal of the catheter does not recover within 8–27 months in most cases. This complication has been recently hypothesized by Imai *et al.*[5] based on autopsy experiments. Direct puncture of the IJV valve was the cause of valvular damage in their experiment, but two other mechanisms may also induce valvular incompetence. The fragile IJV valve may be abraded by the catheter, as previously found in another autopsy study,[1] or the closure of the IJV valve may be impaired by the central venous catheter even though the structure of the IJV valve remains intact. Such temporary interference between catheter and IJV valve may explain the significantly increased valvular incompetence when a catheter was in place and the frequent recovery of competence as soon as the catheter was removed (table 1).

Our study also tends to support the prediction of Imai *et al.* that the probability of inducing valvular incompetence is higher if the IJV is cannulated proximally, *i.e.*, in the area where the IJV valve is located (below the cricoid level; table 1). However, even when the IJV was cannulated more distally (above the cricoid level), incompetence of the IJV valve occurred and persisted after removal of the central venous catheter in 13 of 46 patients (28%). This incidence failed to be significantly lower than that in the proximal cannulation group; however, it should be noted that the power of the study was insufficient to detect a 20% difference. A larger sample size might have provided such significance but would not have changed the clinically significant conclusion that the risk of causing valvular incompetence cannot be eliminated by cannulating the IJV distally.

What is the clinical importance of these findings? First, competence of the IJV valves is considered to be important for protecting the brain from acute increases in intrathoracic pressure, such as during coughing and positive pressure ventilation.[3,5] Although this aspect is of no importance in patients with normal neurology, it might be of importance in patients with compromised cerebral perfusion, *e.g.*, after head trauma or neurosurgery.[7] Second, competence of the IJV valves has been found to be crucial for developing a transcranial blood pressure gradient during cardiopulmonary resuscitation with closed-chest compression.[4] However, the importance of the present findings is unclear because clinical outcome studies are missing. Third, in contrast, a competent IJV valve may impair the efficacy of retrograde brain perfusion during surgery on the aortic arch when the perfusion catheter is located proximally to the IJV valves.[8]

Several limitations of the present study need to be addressed. One limitation is that the cross-sectional area of the IJV at end expiration was significantly larger after surgery (T2 and T3) than at baseline, which may indicate a changed intravascular volume status. One may speculate that the increased size of the IJV may have changed geometry and function of the IJV valve and thus may have been the cause for valvular incompetence in some patients. This assumption is supported by a previous result showing that IJV valves were incompetent in more than 60% of patients with chronically elevated central venous pressure but competent in all patients with normal central venous pressure.[9] Given the correlation between the intravascular pressure (not measured in our study) and the size of a vein,[10] valvular competence at T2 and T3 in our study might have been influenced by the effect of an acutely increased central venous pressure. However, the results of the follow-up study question the importance of this potential confounder because valvular incompetence persisted for months in most patients even though the cross-sectional area of the IJV had decreased and was no longer markedly larger than at baseline. In addition, even if the increased size of the IJV were of some importance, it would not alter the conclusion that competence of the IJV valve may be compromised by cannulation and catheterization of the IJV because valvular incompetence immediately decreased (reaching statistical significance in the proximal cannulation group) after removal of the catheter (T3) although the size of the IJV remained elevated.

Another limitation is that we only studied blood flows and did not perform invasive measurements of the venous pressure on both sides of the IJV valve, as previously performed by simultaneous cannulation of the distal IJV and a subclavian vein.[4,5] However, Doppler ultrasound is an established and reliable method for assessing valvular function[11] and has the advantage of being noninvasive. In addition, the pressure on the proximal side of the IJV valve was standardized by performing all studies during Valsalva maneuvers at an airway pres-

sure of 40 mmHg. The lack of invasive measurement thus does not question our conclusion that most IJV valves are competent and that cannulation and catheterization of the IJV frequently cause incompetence of the IJV valve. Another limitation is that there is no control group, *i.e.*, the assumption was made that cardiac surgery itself does not affect the function of the IJV valve in the absence of IJV cannulation. As a final limitation, the present results only apply to the situation in which 7-French catheters are inserted and may thus not adequately reflect valvular injury caused by larger and stiffer cannula, *e.g.*, 9-French ports for insertion of pulmonary artery catheters.

In conclusion, our study shows that cannulation and catheterization of the IJV may cause persistent incompetence of the IJV valve. Taking a more distal site for venous cannulation may slightly lower the risk of causing incompetence of the valve but does not reliably avoid it.

The authors thank Joan Etlinger, Department of Anesthesia, University of Basel/Kantonsspital, Basel, Switzerland, for editorial assistance.

References

1. Harmon JV Jr, Edwards WD: Venous valves in subclavian and internal jugular veins: Frequency, position, and structure in 100 autopsy cases. Am J Cardiovasc Pathol 1987; 1:51–4

2. Anderhuber F: Venous valves in the large branches of superior vena cava. Acta Anat (Basel) 1984; 119:184–92

3. Dresser LP, McKinney WM: Anatomic and pathophysiologic studies of the human internal jugular valve. Am J Surg 1987; 154:220–4

4. Paradis NA, Martin GB, Goetting MG, Rosenberg JM, Rivers EP, Appleton TJ, Nowak RM: Simultaneous aortic, jugular bulb, and right atrial pressures during cardiopulmonary resuscitation in humans: Insights into mechanisms. Circulation 1989; 80:361–8

5. Imai M, Hanaoka Y, Kemmotsu O: Valve injury: A new complication of internal jugular vein cannulation. Anesth Analg 1994; 78:1041–6

6. Sulek CA, Gravenstein N, Blackshear RH, Weiss L: Head rotation during internal jugular vein cannulation and the risk of carotid artery puncture. Anesth Analg 1996; 82:125–8

7. Sum-Ping ST. Internal jugular valves: Competent or incompetent? Anesth Analg 1994; 78:1039–40

8. de Brux JL, Subayi JB, Pegis JD, Pillet J: Retrograde cerebral perfusion: Anatomic study of the distribution of blood to the brain. Ann Thorac Surg 1995; 60:1294–8

9. Fisher J, Vaghaiwalla F, Tsitlik J, Levin H, Brinker J, Weisfeldt M, Yin F: Determinants and clinical significance of jugular venous valve competence. Circulation 1982; 65:188–96

10. Lobato EB, Florete OG Jr, Paige GB, Morey TE: Cross-sectional area and intravascular pressure of the right internal jugular vein during anesthesia: Effects of Trendelenburg position, positive intrathoracic pressure, and hepatic compression. J Clin Anesth 1998; 10:1–5

11. Magnusson M, Kalebo P, Lukes P, Sivertsson R, Risberg B: Colour Doppler ultrasound in diagnosing venous insufficiency: A comparison to descending phlebography. Eur J Vasc Endovasc Surg 1995; 9:437–43