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Mechanical and infective central venous catheter-related complications: a prospective non-randomized study using Hickman and Groshong catheters in children with hematological malignancies

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Abstract The aim of this study was to compare the Hickman and Groshong central venous catheters (CVCs) for incidence and severity of catheter-related complications in children. Seventy-three patients with hematological malignancies were observed, 42 with Groshong CVCs and 31 with Hickman CVCs. The number of infective episodes per 100 CVC-days was not significantly different (0.25 in the Hickman group versus 0.13 in the Groshong group; $P=0.24$). The most frequent type of CVC-related infection in both groups was microbiologically documented sepsis; in most cases Gram-positive bacteria were isolated. Neutropenia ($P<0.001$ for both CVCs) and hospital CVC management ($P=0.0047$ for the Hickman group, $P<0.001$ for the Groshong group) emerged as the major risk factors for the outbreak of infections. The rate of mechanical complication episodes per 100 CVC-days was similar in both groups (1.01 in the Hickman group versus 1.1 in the Groshong group; $P=0.58$). Some complications (fissures, ruptures, total lumen obstruction by clots) occurred only in the Groshong group. Our study did not demonstrate any statistically significant difference in the incidence of mechanical and infective CVC-related complications between these two types of catheter.

Key words Central venous catheters · CVC-related complications · Hickman CVC · Groshong CVC

Introduction

Intensive treatment can cure patients affected by hematological malignancies formerly considered hopeless. However, easy access to the venous system is mandatory to facilitate support treatment and to achieve successful results. Central venous catheters (CVCs) guarantee reliable access to the bloodstream and are convenient both for the patient and the clinical care staff. Unfortunately, CVCs can also have some disadvantages, such as the risk of mechanical complications (formation of clots, thrombotic occlusions, dislocation, deep venous thrombosis, ruptures, fissures) or infective complications (skin infection at the exit site, subcutaneous tunnel infection, thrombophlebitis, CVC-related septicemia) [6, 9, 29].

While there have been many studies on Hickman-related complications, very few data on the Groshong catheter are available [5, 12, 14, 20].

The most important difference between these two devices is the different form of the catheter tip: the Hickman catheter is open-ended, whereas the Groshong device is valve-ended. The silicone rubber Groshong catheter in fact has a rounded, closed distal tip with an adjacent vocal-cord-type, three-position valve: the valve remains closed when the catheter is not in use, opening outwards if slightly positive, or inwards when a negative internal pressure is applied, to allow infusions or blood withdrawal, respectively. The pur-

pose of this valve is to avoid blood reflux when the CVC is not in use [12].

The main aim of our study was to compare these two devices, evaluating the incidence and severity of mechanical and infective complications.

Patients and methods

Between 1 January 1994 and 3 March 1995, 73 consecutive pediatric patients were studied; 31 had Hickman silicone rubber CVCs and 42, Groshong catheters. Hickman and Groshong CVCs were placed consecutively and alternately, except in a few patients for whom the Groshong device was preferred purely for practical reasons (i.e. shorter duration of anesthesia). As such criteria were not considered to be related to the outcome of interest, i.e. complications, these cases were included in the analysis. A signed informed consent form was obtained in all cases.

The patients had various hematological malignancies, and their characteristics are reported in Table 1. All the malignancies were diagnosed and treated in our Pediatric Hematology Center. Patients were subjected to polychemotherapy treatments according to AIEOP and BFM protocols [3, 7, 24]. Seven children in the Hickman (H) group and 11 in the Groshong (G) group underwent bone marrow transplantation (BMT). The characteristics of the patients are indicated in Table 1.

In the H group, the male/female ratio was 1:1.2 (14 boys and 17 girls), the median age at catheter placement age was 6 years (range: 1–18), the median observation period was 5 months (range: 0.5–14), and the total number of CVC-days was 4,845. In the G group, the male/female ratio was 1:1.1 (20 boys, 22 girls), the median age at catheter placement age was 4 years (range: 1–18), the median observation period was 5 months (range: 0.5–14), and the total number of CVC days was 7,620.

Table 1 Patients' characteristics (*ALL* acute lymphoblastic leukemia, *AML* acute myeloid leukemia, *CML* chronic myeloid leukemia, *CVC* central venous catheter, *SAA* severe aplastic anemia, *NHL* non-Hodgkin lymphoma)

Diagnosis and phase of the disease at CVC insertion	H group (Hickman CVC)	G group (Groshong CVC)
ALL: Onset	15	20
Relapse	6	6
BMT	5	7
Total for ALL	26 (83.8%)	33 (78.6%)
AML: Onset	3	2
Relapse	0	0
BMT	0	1
Total for AML	3 (9.8%)	3 (7.1%)
CML: BMT	1 (3.2%)	1 (2.4%)
SAA: ONSET	0	2
BMT	0	2
Total for SAA	0	4 (9.5%)
Others		
Histiocytosis (BMT)	1 (3.2%)	0
NHL	0	1 (2.4%)
Total	31	42

Both Hickman and Groshong devices were inserted whilst patients were under general anesthesia [4, 26, 31]. Hickman CVCs were all placed in the internal jugular vein, whereas Groshong CVCs were placed in the external jugular, since they are softer and thinner than Hickman CVCs and have smaller internal and external diameters. Therefore, the surgical procedure for placement of Groshong catheters is easier than that needed for Hickman's CVCs and takes less time (about 15 min vs 30 min).

One tip of the catheter was positioned at the superior vena cava outlet in the right atrium and the other tip was tunneled into the subcutaneous tissue, emerging in the anterior thoracic wall medially to the mammary areola. The position of the distal tip was checked during the operation using X-ray contrast to visualize the catheter [4, 9, 23, 25].

Hickman and Groshong CVCs were used both for taking blood and for administering drugs, blood products, and total parenteral nutrition solutions. Only the Hickman type can also be used to monitor central venous pressure [9].

Hickman CVCs were flushed on alternate days with 3 ml of a solution containing heparin, 200 IU/ml, whilst the Groshong type was flushed once a week with 5 ml of physiological solution. Flushing of catheters was carried out according to the manufacturers' recommendations.

A special record form was used to collect the following data for each device: type of disease, date of catheter positioning and removal, description of any complication (mechanical or infective) that developed, therapeutic procedures adopted for both mechanical and infective episodes, patient characteristics at the onset of infective complications (such as the presence of fever or neutropenia, hospital or home CVC management) and course of the complication. Infective complications were defined as home management related or hospital management related if the CVC was used exclusively at home or in hospital in the week preceding the onset of symptoms [4, 22, 28].

With regard to CVC-related infections, the following criteria for diagnosis were adopted: (a) bacterial abscess or cellulitis localized at the exit site or along the subcutaneous tract of the CVC; (b) a 10-fold or greater increase in colony-forming units of organism per milliliter of blood obtained through the device compared with simultaneous peripheral blood cultures; (c) more than 10^3 colony-forming units of organism per ml of blood obtained through the device with negative peripheral blood cultures; (d) bacteremia in which the same micro-organism is isolated simultaneously from a CVC sample and from a swab taken at the CVC insertion site or the catheter hub; (e) temporal relationship between CVC manipulation and the onset of shivering and fever, with or without isolation of a micro-organism from a hemoculture [11, 22, 25, 27, 31].

For the diagnosis of exit site or subcutaneous tract infections, swabs from the skin and hub were made, whilst for the diagnosis of CVC-related bacteremia or sepsis we set up at least two blood cultures (one from CVC and one from a peripheral vein).

With regard to mechanical complications, the major problems taken into consideration were: formation of clots, CVC dislocation, inability to infuse through the catheter or the need for inordinately high pressure for infusion, difficulty in taking blood or complete impossibility, formation of fibrin sheaths on the catheter tip, ruptures and fissures [4, 8, 11, 22, 27, 28].

For the diagnosis of mechanical complications we adopted the following procedures: standard chest radiograph to show CVC dislocation, chest radiograph following infusion of contrast medium through the device when formation of clots or fibrin sheaths were suspected, color Doppler ultrasonography of the incannulated vein to assess vessel wall damage or jugular vein thrombosis [4, 9].

All patients with CVC-related infection received broad-spectrum antibiotic therapy [20]. The antibiotic lock technique was adopted in non-neutropenic patients in the case of bacteremia found only in CVC samples [8, 13, 18, 21, 25].

In the presence of mechanical complications, the following therapeutic procedures were adopted: (a) to resolve partial thrombotic occlusions we used infusions of urokinase (5,000 IU.), which were left in the catheter lumen for 30–60 min, repeatable twice or more; if the occlusion persisted we administered a continuous infusion of urokinase (100–200 IU kg^{-1} h^{-1}) for 24 h; (b) in the presence of small clots in the catheter lumen of the Hickman CVC, the heparin concentration in the saline solution used to flush the CVC was increased to 400 IU/ml and administered on alternate days [4, 8, 17, 19].

CVC removal was indicated if complications (mechanical or infective) did not respond to therapeutic procedures, or in the presence of septic thrombophlebitis [9, 21].

The incidences of mechanical and infective episodes were expressed as rates, i.e. number of events per catheter-days. The incidence rates in the two groups using different CVCs were compared using the statistical test for a binomial distribution [2]. The same approach was adopted to evaluate the importance of neutropenia and home or hospital CVC management in the outbreak of infective complications.

Results

In the H group, at the end of the observation period 20 (64.5%) devices were still in place. We removed 4 catheters (12.9%) electively, 5 (16.1%) as a result of patient death and 2 (6.5%) because of mechanical complications.

In the G group, at the end of the observation period 24 (57.1%) devices were still in place. We removed 7 catheters (16.7%) electively, 6 (14.3%) as a result of patient death and 5 (11.9%) owing to mechanical complications.

None of the patient died of CVC-related complications; no catheter was removed because of infection in either Hickman and Groshong group.

Hickman CVC complications

In all, 20 of the 31 CVCs (64.5%) were affected by complications. The total number of episodes, either mechanical or infective, was 63. CVCs remained in place for a total of 4,845 days; this means there were 3 episodes per 100 catheter-days.

With regard to mechanical complications, 18 CVCs were affected (58.1%), giving an incidence rate of 1.01 episodes per 100 catheter days. Two devices (6.5%) were removed as a result of difficulty or impossibility of taking blood with a poor or nonexistent response to thrombolytic therapy with urokinase and because of catheter malpositioning. The pattern of mechanical complications is indicated in Table 2. As to thrombolytic therapy, the use of urokinase proved to be successful in the presence of clots, solving the problem in 93.3% of cases. When it was not possible to take blood from the CVC urokinase alone solved the problem in 71.4% of cases. Infective complications affected 9 CVCs (29%), giving an incidence rate of 0.25 episodes per 100-catheter-days. No device was removed owing to infection. The pattern of infective complications is indicated in Table 3. Nine episodes occurred with the presence of neutropenia, 3 cases without. The total number of days of aplasia were 432:2.08 infective episodes occurred per 100 days of neutropenia. In the absence of neutropenia (4,413 days), 0.07 infective episodes occurred per 100 days ($P<0.001$). Seven episodes took place during hospitalization, with a rate of 0.66 episodes per 100 days; 5 episodes occurred during CVC use at home, with a rate of 0.13 episodes per 100 days ($P=0.007$). Gram positive bacteria were isolated in 6 cases (*Streptococcus* alpha hemolytic in 2, *Streptococcus pneumon-*

Table 2 Mechanical complications

Type of complication	Hickman (group A)	Groshong (group B)
Aspiration of clots		
No. of CVCs involved (%)[a]	13 (42)	5 (12)
Percent with microclots (<1 cm in lenght)	38	28
Percent with clots (>1 cm in length)	62	72
Inability to withdraw blood		
No. of CVCs involved (%)	6 (19.4)	18 (42)
Completely non-functioning		
No. of CVCs involved (%)	0 (0)	7 (16)
Fibrin sheaths		
No. of CVCs involved (%)	4 (12.9)	3 (7)
CVC dislocation		
No. of CVCs involved (%)	4 (12.9)	7 (16)
Ruptures/fissures		
No. of CVCs involved (%)	0 (0)	5 (12)
Total no. of episodes per 100 CVC-days	1.01*	1.1*

* $P=0.58$

[a] The percentage refers to total number of CVCs in that group

Table 3 Infective complications

Type of complication	Hickman (group A)	Groshong (group B)
Emergency site infections No. of CVCs involved (%)[a]	0(0)	1 (24.4)
Subcutaneous tunnel infection No. of CVCs involved (%)	1 (3.2)	1 (2.4)
Shivering and fever after flushing No. of CVCs involved (%)	1 (3.2)	0 (0)
Sepsis with microbiologically documented infection No. of CVCs involved (%)	7 (22.6)	8 (19.1)
Total no. of episodes per 100 CVC-days	0.25*	0.13*

* $P = 0.24$
[a] The percentage refers to total number of CVCs in that group

iae in 1 and *Staphylococcus epidermidis* in 3), and Gram-negative bacteria in 3 cases (*Escherichia coli* in 1, *Pseudomonas aeruginosa* in 1 and *Agrobacterium* of unidentified species in 1). Two devices were affected by two or more infective episodes (6.5%) and 1 device was affected by infective episodes in association with clot formation. During hospitalization, Gram-positive bacteria were isolated in 4 cases and Gram-negative bacteria in 1 case. All infectious episodes resolved with antibiotic treatment.

Groshong CVC complications

Overall, 28 CVCs out of 42 (66.6%) were involved in mechanical or infective complications. The total number of episodes (either mechanical or infective) was 95 over a period of 7,620 days; in other words, 1.2 episodes occurred per 100 catheter days.

Mechanical complications (Table 2) affected 24 catheters (57.1%), with an incidence rate of 1.1 episodes per 100 CVC-days. Five devices (11.9%) were removed because of complete lumen obstruction by clots (2 cases), impossibility of taking blood, not improved by thrombolytic therapy (2 cases) or repeated episodes of CVC ruptures (1 case). Two Groshong devices were double-lumen types: they were both affected by clot formation with total lumen occlusion. The use of urokinase resolved the problem of clots in 60% of cases; in the case of catheters from which it was impossible to take blood or not functioning either in aspiration or in infusion, urokinase proved successful in 61.1% and 14.3%, respectively.

Infective complications (Table 3) affected 9 catheters (21.4%), giving an incidence rate of 0.13 episodes per 100 CVC-days. No device was removed owing to infection. Eight episodes occurred with the presence of neutropenia, 2 episodes without; 1.76 infective episodes occurred per 100 days of neutropenia (number of days of aplasia was 455); in the absence of neutropenia (total 7,165 days) 0.03 episodes occurred per 100 days ($P < 0.001$). Eight episodes occurred during hospital CVC use, with a rate of 0.49 episodes per 100 days; 2 episodes occurred during home use, giving a rate of 0.03 episodes per 100 days ($P < 0.001$). Infective complications involved Gram-positive (*Streptococcus* alpha hemolytic in 1 case, *Streptococcus* beta hemolytic in 1 case, *Streptococcus* of unidentified species in 1 case, *Staphylococcus epidermidis* in 1 case) and Gram-negative (*E. coli* 1, *Pseudomonas* of unidentified species 1, unidentified bacterium 1) bacteria, and mycetes (*Candida albicans* 1). Only 1 device was affected by two or more infective episodes (2.4%) and only 1 device, by an infective episode in association with clot formation. During hospital CVC management, Gram-positive bacteria were isolated in 57.1% of cases (4 episodes), whereas at home there were only 2 episodes, in which Gram-negative bacteria were isolated. All infectious episodes resolved with antibiotic and antifungal treatment.

Discussion

In our study we observed 31 Hickman CVCs and 42 Groshong devices positioned in two similar groups of patients affected by hematological malignancies. The aim of our study was to compare the advantages and disadvantages of these two devices to allow us to recommend preferential or elective application criteria for one of the catheters. Data based on our past experience with Hickman catheters only is reported elsewhere [4, 8, 25, 28].

We introduced the Groshong type in 1994, as it was considered to be more effective largely because of the presence of a valve that can prevent blood withdrawal in the lumen when the device is not in use, and also because of easier management procedures with a possible lower risk of infection outbreak [1, 4–6, 9, 12, 29]. The Groshong type might be less problematic for relatives, and the number of CVC manipulations is lower:

hand contact is considered an important risk factor in the outbreak of infective complications. To our knowledge, published data regarding Groshong CVC use in pediatric patients is not available. Minimal information about the incidence of mechanical complications is reported and does not confirm the supposed superiority of the Groshong type CVC over the Hickman one [12, 20].

No patient died of CVC-related infections, and the total incidence of infective episodes was very low: only 0.25 episodes per 100 catheter-days for the Hickman type and 0.13 episodes per 100 catheter-days for the Groshong type, whereas published data reflect between 0.27 to 0.68 episodes per 100 days in immunodepressed patients [11, 25, 27].

In our experience no significant difference was noted between Hickman and Groshong catheters with regard to the incidence of infective episodes ($P=0.24$). For both types, the incidence of infective episodes was significantly higher during a neutropenic phase ($P<0.001$ for both CVCs) [8, 25, 28, 30]. Hospital CVC management appeared to be related to a higher incidence of infective episodes than CVC use at home, in both the Hickman and the Groshong group ($P=0.007$ and $P<0.001$, respectively); we attribute this to the critical condition of hospitalized patients and the large number of manipulations performed during hospitalization. For the incidence of infective episodes in hospital there was no statistically significant difference between the Groshong and Hickman groups ($P=0.59$). The same was true for the incidence of infective episodes at home ($P=0.19$).

Gram-positive bacteria were primarily isolated, confirming the important role of hand manipulation in the outbreak of infective CVC-related complications [11, 18, 22, 25, 30, 31]. No catheter had to be removed because of an infective episode, because the antibiotic treatment resolved all infective episodes both in the Hickman devices and in the Groshong lines.

Our study did not confirm an association between clot formation and infective episode incidence, as has been reported in the literature [4, 16, 26]: in fact most infective complications occurred independently of mechanical complications.

Regarding major mechanical CVC-related complications, no case of pulmonary embolism or vena cava thrombosis occurred [10, 15, 23]. There was no statistically significant difference between the Hickman and the Groshong groups in the incidence of mechanical episodes ($P=0.58$), according to the available data [5, 12, 20]. In the presence of clots, therapy with urokinase resolved 93.3% of such cases in the Hickman group, and 60% of those in the Groshong group: in cases where it was not possible to withdraw blood, the percentage of episodes resolved by urokinase was greater in the Hickman group than in the Groshong group (71.4% versus 61.1%). Our experience demonstrated that thrombolytic therapy with urokinase can produce excellent results if applied promptly by trained doctors or nurses and makes it possible to avoid major mechanical complications [10, 15, 19, 23].

Catheter ruptures and fissures only occurred in the Groshong group: while this device is softer and thinner than the Hickman CVC's which makes surgical insertion easier, it has proved to be excessively sensitive to mechanical traumatisms. Furthermore, this extreme softness makes it impossible to remove Groshong catheters with a resolute traction by hand (unlike the Hickman type); removal of a Groshong CVC requires a surgical procedure under anesthesia.

Another type of mechanical complication was seen more frequently in the Groshong than in the Hickman catheter, namely device dislocation in the right ventricle or in the upper part of the superior vena cava. This arises from the considerable thinness of the Dacron felt cuff, making the Groshong-type catheter less firmly fixed to the subcutaneous tunnel than the Hickman line.

In conclusion, both types of devices proved appropriate in the management of multiple drug administration to the immunosuppressed patients being monitored in our Pediatric Hematology Unit. No major infective or mechanical complications emerged thanks to careful training of both nurses and parents throughout the study period. As expected, neutropenia was the most important risk factor for the outbreak of infections. Minor mechanical complications, although frequent, usually responded to appropriate therapy.

Our study does not demonstrate any real advantage to using Groshong catheters. In fact, neither infective nor mechanical complications differed significantly in frequency between the two catheter types. However, the more expensive Groshong CVC, being easier and quicker to insert and having smaller internal and external diameters, might be used in selected cases of very young children who have small veins, or in patients for whom a prolonged anesthesia or a more invasive procedure might be a risk and a shorter operating time is advisable.

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