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Complications in the use of intravenous catheters for major surgery: A clinical study

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Abstract: Two groups of patients received one of two intravenous catheters, a 20-gauge (ga) Criticon (C group; $n = 96$) or a 20-gauge (ga) Vitaflon Plus (V group; $n = 100$). Each catheter was inserted under identical cannulation conditions. Fluids and drugs used pre- and postoperatively were comparable in both groups. All catheters remained in place for a minimum of 4 days. Variables related to the quality of cannula were more favorable with the V group catheter. The incidence of early complications (erythema, swelling, tissue hardness, pain) was comparable in both groups. The survival distribution curves for all complications and swelling >2 cm were significantly longer in the V group. The frequency of swelling correlated with difficulty during vein penetration, slow blood flashback, and damage to the catheter. The incidence of complications following cannulation was high in both groups. The period from catheter insertion to the clinical onset of phlebitis was prolonged in both groups if antiphlebitogenous fluids were used. The incidence of late complications (phlebitis, displacement of the cannulae, etc.) and damage to the catheters was more frequent in the C group. The authors discuss the clinical relevance of these findings.

Key words: Anesthetic complications, I.V. cannulation, I.V. fluids, Phlebitis

Introduction

Appropriate surgical and anesthesiological treatment of patients can occur only with adequate intravenous infusion. Our research interests have ranged from evaluation of the unpleasant pain experienced during vein puncture to the serious complications associated with intravenous catheters such as thrombophlebitis and embolisms. The aim of this clinical study, carried out in the Utrecht University Hospital, was to evaluate the prevalence and severity of complications arising from peripheral intravenous cannulation for major surgery. A comparison was made between two similar high-quality infusion catheters.

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Materials and methods

The Ethics Committee of the Utrecht University Hospital evaluated and approved the research protocol. A total of 196 patients who were to undergo major abdominal operations were selected. On the basis of inclusion and exclusion criteria (Table 1), two intravenous catheters were used:

1. A 20-gauge Criticon (Criticon, Tampa, FL USA) with a 32-mm Teflon (Criticon group), nonradiopaque catheter, 1.05 mm in diameter
2. A 20-gauge Vitaflon Plus (Ohmeda, Helsingborg, Sweden) with a 32-mm "bio-material" Topecon, (Vitaflon group), nonradiopaque catheter 1.10 mm in diameter

Two hundred envelopes were numbered consecutively. In each envelope, there was either a Criticon or a Vitaflon Plus infusion catheter, a three-way tap with extension tubing, a VECA-C infusion fixative, alcohol swabs, a set of registration forms, a numbered "clinical trial" sticker, and a bag in which to save the catheter after removal.

In the operating theater an infusion catheter from one of the numbered envelopes was introduced into the patient. The intravenous catheter was always introduced by the same person, who did not know in advance which catheter he would be using. The catheter was always introduced into a vein on the dorsal side of the nondominant forearm. If the radial artery had to be cannulated, it was done on the contralateral arm. If

Table 1. Research criteria

Inclusion criteria
1. Operations longer than 2h
2. No dermatologic infections on the arm to be cannulated
3. No dermatologic disorders
4. No sepsis
5. No neurologic defects of the arm
6. Catheter to remain a minimum of 4 days in situ
7. Patient's age between 20 and 60 years
8. Patient's weight between 50 and 100KG
Exclusion criteria
1. Any symptoms of inflammation
2. Thrombophlebitis
3. Operations shorter than 2h
4. Damage to the catheter during insertion
5. Patients weighing more than 100KG
6. Patients receiving long-term parenteral nutrition
7. Patients who carry/wear a catheter
8. Patients with liver or kidney disorders

necessary, a central venous or pulmonary catheter was introduced into the internal jugular vein.

The research infusion catheter (RIC) was introduced under stringent aseptic conditions. The person placing the catheter washed his hands and wore sterile gloves. The patient's skin was disinfected with alcohol. The RIC was introduced, and the three-way tap with extension tubing filled with 0.9% NaCl was attached and secured with a VECA-C dressing. This dressing also covered the hub of the catheter so that identification of the catheter would not be possible postoperatively. The numbered "clinical trial" sticker was affixed.

Items evaluated during the intravenous cannulation were:

1. Piercing of the skin in the vein
2. Penetration of the tip of the needle during the puncture
3. Filling of the chamber of the needle with blood (flashback)
4. Advancing the catheter from the needle
5. An overall impression of the cannulation procedure

Each item was assessed on a three-point scale:

— Very easy
— Not difficult
— Very difficult

The RIC alone was used for intravenous therapy during and after the operation. All infusion fluids, blood, heparin, corticosteroids, antibiotics, and other medications were administered through the RIC. Measurements in the radial artery and pulmonary vein were done for hemodynamic evaluation only.

All patients were operated on under general anesthesia whether in combination with an epidural block or not. The patients were mechanically ventilated with nitrous oxide: oxygen 2:1. The infusion rate was between 10–12 $ml \cdot kg^{-1} \cdot h^{-1}$ during the operation and 50 $ml \cdot kg^{-1}$ per 24h following surgery in both groups. Another member of the research team monitored the RIC twice a day postoperatively, and all reactions relating to the RIC were documented. The RIC remained in situ for a minimum of 4 days (96h).

The RIC was removed earlier if:

1. The medical intravenous treatment had been completed.
2. Early (erythema, swelling, hardness, pain) or late (thrombophlebitis) inflammatory symptoms around the cannulation site or subsequent path of the cannulated vein were noted.
3. The RIC was moved subcutaneously.
4. The RIC was bent.
5. The RIC was disconnected or blocked.

Before the RIC was removed, the presence of pain and the extent of the inflammatory symptoms were documented. The presence of pain was assessed using a hand dynamometer, which applied a fixed pressure of 2N on the RIC. If the pressure of the dynamometer produced a pain score of 5 or higher on a visual analogue scale of 0–10, this was recorded.

The extent of erythema, swelling, and tissue hardness was registered according to the following scale:

— No reaction
— Less than 1cm
— Between 1 and 2cm
— Larger than 2cm

The RIC was examined microscopically after removal. The extent of damage to the RIC was registered according to the scale of Gaukroger et al. [1].

Statistics

Differences between the two catheters were evaluated by the chi-squared test (Yates' correction) or the Fisher's exact test (if there were small expected frequencies). For some variables, the mean values were compared using the "two-sample *t*-test". This test was used for age, weight, length, and the parameters relating to introduction of the RIC. The Pearson correlation coefficient was used for the correlation between the frequency of swelling and difficulty in introducing the RIC. "Survival times" were compared using the log-rank test. A difference of 5% was considered to be significant.

Results

A total of 196 RICs were studied. There was no significant difference between the C group and V group in

Table 2. Patient profile

Catheter	Age(years)	Sex	Weight(kg)	Height(cm)
Criticon	47.9 ±19.1	Women = 53 Men = 43	70.7 ±13.5	172.8 ±8.0
Vitaflon	51.3 ±18.5	Women = 59 Men = 41	68.6 ±13.6	170.6 ±8.9

Two-sample *t*-test.

Table 3. Cannulation

	Catheter	Very easy	Not difficult	Very difficult
Piercing skin $P = 0.029$	Criticon	27.1%	59.4%	13.5%
	Vitaflon	38.0%	56.0%	6.0%
Piercing vein $P = 0.022$	Criticon	26.0%	59.4%	14.6%
	Vitaflon	36.0%	56.0%	8.0%
Flashback $P > 0.001$	Criticon	8.3%	28.1%	63.6%
	Vitaflon	36.0%	58.0%	6.0%
Resistance $P = 0.017$	Criticon	25.0%	60.5%	14.5%
	Vitaflon	34.0%	59.0%	7.0%
Removal of needle $P = 0.013$	Criticon	25.0%	59.4%	15.6%
	Vitaflon	38.0%	55.0%	7.0%
Placing catheter $P = 0.015$	Criticon	25.0%	57.3%	17.7%
	Vitaflon	37.0%	54.0%	9.0%

Two-sample *t*-test.
Very easy = Direct cannulation of the vein at the first attempt, rapid blood flow into the chamber (flashback), easy removal of the needle; Not difficult = No special remark/observation/comment during cannulation; Difficult = Two or more attempts to penetrate the skin and vein, or resistance or friction between the needle and catheter during removal of the needle, attempts to place the catheter, or combinations of these.

relation to the patient profile (Table 2). Conditions of venous puncture were comparable between the groups:

— Visible vein 76% in the C group; 80% in the V group
— Palpable vein 82% in the C group; 83% in the V group
— Ideal size of the vein; 72% in both groups

Parameters studied relating to the introduction of the intravenous cannulation were significantly better in the V group than in the C group (Table 3).

The duration of catheter insertion was comparable between the groups:

— 76 h median (maximal 192, minimum 20) in the C group
— 71 h median (maximal 310, minimum 16) in the V group

The occurrence of pain, erythema, swelling, and/or hardness around the insertion site, along the RIC, and/or at the RIC tip, was comparable in both groups. The occurrence of erythema, swelling, and/or hardness greater than 2 cm was also comparable in the two groups.

The time interval between the insertion of the RIC and the occurrence of any early inflammatory symptoms around the RIC larger than 2 cm (Fig. 1) was significantly longer in the V group as compared to the C group ($P < 0.02$). A comparison between the groups of this interval using the log-rank test demonstrated that there was a significant difference in favor of the V group ($P = 0.015$). The difference between the groups in the survival distribution curve larger than 2 cm was statistically significant only with the symptom of swelling and was in favor of the V group.

The occurrence of swelling at the puncture point, around the RIC, and at its tip corresponded with the degree of difficulty in cannulating the vein ($P = 0.05$). Furthermore, it became evident that difficulty both in filling the chamber of the needle and with tissue swelling ($P = 0.05$) caused damage to the tip of the RIC ($P < 0.001$).

The osmolarity of the fluids administered by the RIC during the investigation was similar in both groups:

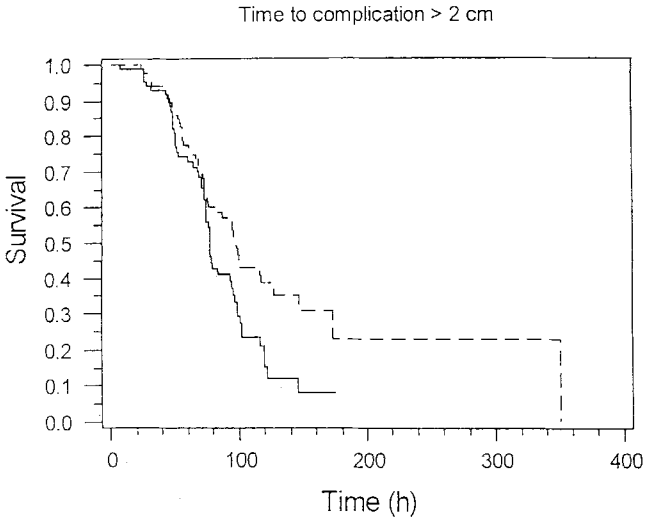

Fig. 1. Comparison of cannulae. *solid line*, Critikon; *broken Line*, vita flow

406 mmol/l in the C group and 412 mmol/l in the V group. The number of patients receiving antibiotics, corticosteroids, and heparin during the study was comparable in both groups (46% in the C group and 42% in the V group). Occurrence of early inflammatory symptoms was higher for the administration of phlebitogenous fluids alone (e.g., antibiotics) than for the administration of a combination of antiphlebitogenous (corticosteroids, heparin) and phlebitogenous fluids. The time interval between the insertion of the RIC and the occurrence of phlebitis was longer in patients who had received antiphlebitogenous medication than in patients who had been given antibiotics only, irrespective of the sort of intravenous catheter used ($P = 0.02$).

Removal of the RIC due to "completion of therapy" occurred more frequently with the V group (51%) than with the C group catheters (26%). Phlebitis, subcutaneous insertion (including subcutaneous infiltration and leakage), bending, disconnection, and blockages of the RIC by coagulation occurred more frequently in the C group than in the V group catheters. Microscopic evaluation of the RICs after removal showed that the Vitaflon Plus catheters had sustained less damage than the Criticon catheters (Table 4).

Discussion

The circumstances under which the RICs were inserted were for all practical purposes identical:

— The vein on the dorsal side of the forearm was cannulated.
— The largest vein possible was chosen.
— The cannula (20 gauge) was relatively small, making it easier to perform the cannulation.
— The procedure was conducted under sterile conditions.

These measures were designed to avoid a subcutaneous or venous hematoma during insertion of the RIC and damage to the tip of the RIC, thus preventing early inflammatory symptoms such as erythema, swelling, hardness, and pain, and the later complications of thrombus formation and thrombophlebitis.

Favorable characteristics (visible, palpable, and ideal cross-section) and unfavorable characteristics (not visible, not palpable, and small) of the veins catheterized were comparable between the two groups. It was noted that the unfavorable venous characteristics frequently occurred in both groups (17%–28%). Whether this would be a consistent finding in patients requiring major operations is open to discussion.

Comparison between the two catheters in regard to ease of piercing through the skin into the vein showed clearly that the Criticon needle is less sharp than the Vitaflon Plus. Moreover, the backflow of blood into the chamber of the needle after the tip has been inserted into the vein is significantly faster in the V group than in the C group.

Faster filling of the catheter chamber gives a better indication during insertion as to whether the needle has been correctly placed intravenously. When filling of the chamber proceeds slowly, the position of the needle may be incorrectly assessed, making a new attempt necessary. In addition, easy withdrawal of the needle from the catheter is an important technical aspect. With less friction between the needle and the catheter, there is less possibility of damaging the catheter during withdrawal of the needle.

In short, the goaling of the catheter material can affect the degree of trauma sustained by tissue during placement of an intravenous line. Minimizing trauma can result in a reduction in the occurrence of early and later complications. Our results confirm those of Maki and Ringer [2], who found that uncomplicated introduction of a catheter results in less frequent infusion-related complications.

The occurrence of early inflammatory symptoms was high, being approximately 30% in both groups. A pos-

Table 4. Catheter tip distortion

Catheter tip	Criticon	Vitaflon
Normal	48.8%	87.5%
Distorted	23.9%	8.0%
Slightly damaged	8.0%	3.4%
Very damaged	19.3%	1.1%

Chi-squared test = $P < 0.001$.

sible etiology of the early inflammatory symptoms is trauma to the endothelium of the vein caused by the change in shape of the RIC during insertion and guidance of the catheter. The early inflammatory symptoms are sustained or aggravated by intravenous fluids and medicines administered during and after surgery.

It was noted that administration of heparin and corticosteroids lowered the frequency of complications. We suggest that administration of small amounts of these two antiphlebogenous medications could prevent the occurrence of early inflammatory complications. Later complications of peripheral intravenous catheters may also be prevented in the same way. Our data suggest that all antibiotics would best be administered through a central catheter to avoid adverse reactions of the peripheral venous system to antibiotics.

The occurrence of phlebitis in the V group of our study was less frequent than Maki and Ringer [2], Hecker et al. [3], and Lewis and Hecker [4] have reported. They noted a frequency between 30% and 70%, which is in accordance with the occurrence rate we found in the C group. The presence of early inflammatory symptoms and particularly phlebitis is an indication to remove an intravenous catheter. Events of this kind entail a rise in the costs of intravenous therapy.

Microscopic evaluation of the tip of the RIC demonstrated that more than 50% of the Criticon catheters were bent out of shape or damaged during use. This corresponds to the findings of Treuren and Galletley [5], who reported that 54% of the Jelco catheters incurred distortions of the tip. The differences between the Vitaflon Plus and the Criticon catheters were highly significant. The damage to the Criticon catheters correlated with the difficulty of intravenous insertion and the factors which caused the inflammatory complications, swelling in particular.

Conclusion

The development of complications following peripheral intravenous cannulation is frequent in patients who have to undergo a major operation. Many factors underlie these complications. Use of the best-designed catheter and nontraumatic insertion can prevent or delay the occurrence of early and late inflammatory symptoms. The use of phlebitogenous fluids and medicines, subcutaneous shifting of the catheter, leakage, obstruction, disconnection, and bending of the catheter can lead to the development of thrombophlebitis and possibly embolisms. Prevention of these complications by the use of corticosteroids and heparin and the administration of antibiotics through the central lines could reduce the costs of intravenous therapy and extend the duration of catheter placement in the postoperative phase.

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