More Effective Prevention of Incompatibility Reactions Through the Use of Four Lumen Central Venous Catheters in Critically Ill Patients

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Abstract:
We evaluated potential practical benefits of the use of four lumen central venous catheters (CVCs) in critically ill patients in intensive care units (ICUs). Intensive care specialists assessed ease of handling during catheter insertion and ICU nurses determined whether adequate flow rates can be achieved with four lumen CVCs. We also determined to what extent strictly dedicated medication lumen use can reduce or eliminate compatibility problems when using four lumen CVCs. Quadruple lumen catheters meet ICU needs not adequately addressed with either triple or five lumen CVCs. Four lumen catheters are easy to handle and achieve the flow rates needed for specific indications and drugs. Compared with three lumen catheters, four lumen CVCs enable more strictly dedicated, well structured lumen use for TPN and drugs, thus significantly reducing compatibility problems. Facilitating catheter handling and reducing ICU costs, four lumen catheters may thus be a useful alternative to either triple or five lumen CVCs.

Key Words
Incompatibility reactions
Four lumen (central venous) catheters
Flow rates
Safety
How Many Catheter Lumens Do Critically Ill Patients Need?

Early on in our study, we found that there was no such thing as an ideal type of central venous catheter (CVC) that would fit all clinical situations. The decision for or against a particular catheter should rather be based on a number of most different clinical parameters including clinical indication(s), catheter handling characteristics, required flow rates, and ICU medication needs.

Potential incompatibilities of (total) parenteral nutrition solutions and/or ICU drugs are increasingly being considered in deciding whether or not to use a multi-lumen catheter. Awareness of potential incompatibilities has heightened among ICU nurses in particular as a huge number of new drugs have been introduced in ICUs in recent years while little or nothing is known about their stability and compatibility with other drugs. Also, the product labeling of a growing number of drugs urges "administration via a separate line", more or less inevitably necessitating the use of additional venous access lines to avoid problems with drug incompatibilities and/or liability issues.

(Figure 1)       (Figure 2)

Inappropriate pH in a stopcock manifold causes midazolam to precipitate: At pH 6 in the infusion line, large amounts of free base precipitate.

Calcium phosphate precipitates when administered via a TPN line.

Double lumen catheters are a major improvement over single lumen catheters in that the former enable the simultaneous administration of medications via peripheral access devices. The limitations of double lumen catheters become evident in patients with multiple pathologies requiring multiple drugs. While potential medication compatibility problems may occasionally be addressed through dosage form modification, (drug) administration via peripheral lines, or even the use of an enteral feeding tube, specific pharmacologic properties, such as extremely short half-lives, unique formulations, or the addition of yet other medications, frequently defeat these dosing strategies. Also, it is now generally accepted that optimum ICU patient care depends on the use of a dedicated total parenteral nutrition (TPN) catheter lumen to ensure the continuous delivery of essential nutrients while avoiding adverse chemical/physical interactions, or incompatibility reactions, as far as possible. The need for a third line or lumen thus becomes evident once a patient needs to start TPN.
This need has been addressed through the introduction of triple lumen central venous catheters (CVCs). In many ICU settings, triple lumen CVCs enable TPN delivery, drug administration, and appropriate monitoring of critically ill patients with relatively few or no problems, while achieving excellent flow rates. Catheter insertion by the Seldinger technique, intraatrial electrocardiography, and hence the overall simpler handling of multi-lumen catheters have combined to encourage many ICUs to use triple lumen CVCs as the standard catheter for their critically ill patients. While the introduction of three lumen catheters initially appeared to be a quantum leap in avoiding compatibility problems, the increasing complexity of treatment regimens very soon pointed up the limitations of triple lumen CVCs. In fact, many ICU patients required placement of one or more peripheral access devices in addition to their triple lumen catheter. This development has recently prompted us to systematically collect and analyze queries regarding this issue in an effort to develop a safe as well as practicable approach to multi-lumen CVC use for effective management of TPN and/or medication delivery and ICU monitoring. Based on this data collection and the findings of specific investigations into this issue (Four Lumen CVC Study), we will now compare triple lumen CVCs with four lumen CVCs in terms of incompatibility reaction avoidance, achievable flow rates, and ease of handling.

Patients, Methods, and Materials (Four Lumen CVC Study)

During a 6-month period, 100 heart surgery ICU patients (80 male and 20 female patients) in two intensive care units each had a 20-cm four lumen catheter (Certofix® Quattro, B. Braun Melsungen, Melsungen, Germany) inserted, preferably via the right internal jugular vein, or, in some cases, via the right subclavian vein. Accurate catheter tip placement was readily verified by intraatrial electrocardiography.

The patients' mean age was 65.5 years (14-90), and American Society of Anesthesiologists (ASA) risk classification showed that 87 patients were ASA III and 3 patients were ASA IV, while 10 patients were not ASA classified. The CVC was in place for an average period of 3.6 days (1-21 days). Flow rates, especially that through the main channel (14 gauge), and catheter handling (8 French; each French unit is roughly equal to 0.33 mm) were assessed by intensive care specialists and ICU nurses using predefined rating scales (1 = excellent...6 = very poor). Moreover, 50 infusion regimens from a database were reviewed for potential compatibility problems. First, all infusion regimen elements were analyzed for possible incompatibilities with one another. Next, the drugs were assigned to the lumens available in a triple lumen CVC and to those in a four lumen CVC, documenting any remaining incompatibility reactions. To rule out assigner bias as far as possible, medication and TPN assignment to the various lumens was performed using a special database program rather than manually. The lumen assignment suggested by the computer program was manually "post-edited" only in a second step, if necessary. To determine the potential utility of four lumen catheters also for more complex infusion regimens, this procedure was also applied to 50 infusion regimens from various ICUs documented in the above database compiled in recent years.
Results and Discussion
Closer inspection of our data very quickly revealed the benefits of four lumen CVCs. The 14 gauge (G) lumen of the "main channel" of four lumen catheters enables the delivery of large fluid volumes (60 mL/min) and such monitoring activities as measurement of the central venous pressure (CVP).

The flow rates achieved through the main lumen were clinically rated "excellent" in 95% of cases and "good" in 5% of cases. Also, the "side channels" (two 18 G lumens and one 16 G lumen) enable flow rates of 23 mL/min (18 G) and 53 mL/min (16 G). Most of the regimens we analyzed included TPN and a reasonably small number of drugs. The number of theoretically possible incompatibility reactions was correspondingly small. The greatest number of such reactions was 25, and the smallest was 3. The average number of incompatibility reactions to consider in those infusion regimens was 3–4, suggesting, at first glance, that the use of quadruple lumen catheters may not be justified. In clinical practice, however, four lumen CVCs permit very easy and straightforward medication assignment to the various lumens, thus enhancing patient and product safety. The most surprising finding, though, was that all potential incompatibility reactions of all heart surgery infusion regimens studied could be readily avoided when using four lumen CVCs.

(Figure 3)

Quadruple lumen catheters accommodate the option of dedicating a separate lumen to such critical drugs as catecholamines, leaving three lumens for delivery of larger fluid volumes and administration of other medications.
In the regimens we analyzed, dedicated lumens were even available for patients who required TPN and additional fluid as well as catecholamines and other medications, also easily accommodating any monitoring activities that may have been required. The peripheral access device typically in place in such (critically ill) patients can be used almost exclusively for blood draws and, if necessary, for administering problem medications, such as brief infusions of antibiotics. ICU infusion regimens are associated with a multitude of (potential) compatibility problems, as expected. The average number of theoretical incompatibility reactions associated with the regimens we analyzed was 15 to 20. This is due to the frequent need to simultaneously administer numerous drugs. In fact, critically ill patients not infrequently need as many as 40 to 50 intravenous doses a day. While significantly reducing potential compatibility problems, triple lumen CVCs are typically an unsatisfactory half-way solution. Indeed, ICU patients requiring parenteral nutritional support and simultaneous catecholamine infusion have only one lumen left for the administration of all other drugs. This shortcoming of triple lumen CVCs almost invariably necessitates the placement of an additional, typically peripheral, access device for administration of one or more drugs. In clinical practice, this often gives rise to doubts as to which drugs can actually be safely administered via this peripheral line. There is also much uncertainty about what drugs are compatible when administered via a peripheral line and whether flushing is required between administrations and what solutions are suitable for flushing. This approach also depends on knowledge of such medication parameters as titration acidity, osmolarity, and pH, but this information is not usually available to users. Four lumen CVCs, on the other hand, usually enable the separate administration of TPN and most medications, thus significantly reducing potential incompatibility reactions via these central venous access devices. Quadruple lumen catheters are amenable to standard assignment of TPN and medications to dedicated lumens for the majority of infusion regimens, also addressing potential compatibility problems.

Figure 4)

Four lumen CVCs accommodate complex infusion regimens while preventing incompatibility reactions.
Moreover, quadruple lumen CVCs allow ICU specialists to assign a dedicated lumen to critical drugs, such as catecholamines, thus ensuring that these vital drugs can be given as needed at all times. Exceedingly complex regimens, however, may require a separate peripheral venous access device for critical drug delivery even when using a four lumen CVC. The potential use of a five lumen catheter should be critically evaluated in such cases. Apart from such exceptional clinical situations, the use of four lumen CVCs enhances safety in the ICU in terms of integrity of drug delivery and hence efficacy by minimizing the risk of incompatibility reactions which might lead to loss of efficacy or even the formation of toxic products. When weighing the pros and cons of four lumen CVCs, this aspect is not only medically significant but should also be considered by hospital administrators concerned with cutting overall healthcare costs.

**Conclusion**

Four lumen catheters have primarily been designed to facilitate the administration of infusion regimens that involve the infusion of large fluid volumes as well as the administration of TPN solutions and multiple medications. Quadruple lumen CVCs are a major improvement over triple lumen CVCs in a number of clinical settings including oncology and heart surgery.

The investigations and analyses presented in this paper show that, depending on the clinical situation at hand, four lumen CVCs may be a useful alternative to either three or five lumen CVCs. The major advantage of quadruple lumen catheters over triple lumen CVCs is that the former enable strictly dedicated lumen assignment for both TPN and different medications, thus eliminating the risk of incompatibility reactions in many settings. Four lumen CVCs also accommodate the option of delivering large fluid volumes via the main channel (14 gauge). Compared with five lumen catheters, quadruple lumen CVCs are a rational choice whenever an ICU patient needs TPN solutions and a limited number of drugs that can be accommodated by two medication channels, and if the patient is not expected to require additional drugs for the management of unforeseen complications. In such cases, four lumen CVCs are also less costly and, therefore, appealing to hospital administrators.

The "locking off" of individual lumens when reducing the number of drugs in a regimen has deliberately been excluded from this discussion of multi-lumen catheters. A more complex study of this issue is clearly needed because there is as yet no uniform, reliable guidance on this important and interesting aspect.

**Conflict of interest statement**

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References


Infusion regimens from various ICUs documented in the above database compiled in recent years.

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