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TECHNOLOGY, COMPUTING, AND SIMULATION

The Effects of Multiple Infusion Line Extensions on Occlusion Alarm Function of an Infusion Pump

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Abstract

BACKGROUND: For anesthesia or conscious sedation of patients undergoing diagnostic or therapeutic procedures in computed tomography or magnetic resonance imaging scans, an extension of infusion lines for continuous drug delivery of anesthetics or vasopressors is often necessary. In this study, we tried to determine if the length of the infusion line influenced the time until an alarm sounded after occlusion at the end of the infusion line.

METHODS: We connected 2 infusion pump systems of the same model with 1, 2 or 3 infusion lines in series or with a spiral nonkinking low compliance infusion line, and started the infusion for 60 s. The end of the infusion line was then occluded by turning a stopcock to occlude the fluid flow. A pressure sensor was connected to the infusion line to record the actual pressure change in the line. The time until the pressure occlusion alarm sounded was measured 5 consecutive times at flow rates of 5, 20, and 50 mL/h.

RESULTS: When using a single infusion line, pressure occlusion alarms were triggered after 2.4 ± 0.1 min for infusion pump 1 and 2.6 ± 0.2 min for infusion pump 2 at 50 mL/h, after 6.6 ± 0.4 min and 5.6 ± 0.5 min at 20 mL/h, and after 23.0 ± 2.8 min and 20.9 ± 3.6 min at 5 mL/h, respectively. When adding a second infusion line, a pressure occlusion alarm was triggered after 27.1 ± 1.8 min for infusion pump 1 (P = 0.1) and after 29.2 ± 1.4 min for infusion pump 2 (P = 0.07) at 5 mL/h. With 3 infusion lines, the pressure occlusion alarm of infusion pumps 1 and 2 were significantly prolonged when compared with 1 infusion line and were released at 31.6 ± 3.0 min (P = 0.01) and 35.1 ± 1.1 min (P = 0.001) at 5 mL/h, respectively. The pressure level triggering an alarm ranged in both infusion pumps between about 900 and 1100 Mbar.

CONCLUSIONS: When simulating low flow rate infusions (5 mL/h) as for vasopressor support, occlusion alarm time was critically prolonged, especially with an increased length of infusion lines.

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The number of diagnostic and surgical procedures being performed outside of core operating rooms is growing disproportionately in relation to the total number of diagnostic and surgical procedures.[1] Patients being treated in these locations are usually older and sicker than average[2] and may require accurate continuous drug infusions, e.g., of vasoactive drugs. This may pose problems since it is often not possible to take infusion pumps inside a magnetic resonance imaging (MRI) suite,[3] thus requiring several infusion line extensions to connect the infusion pump outside of the MRI suite to the patient. Furthermore, during interventions or diagnostic procedures in a computed tomography scan, the operating table has to be moved often, which requires an extension of infusion lines as well. Thus, an accidentally closed stopcock or kinked infusion line may cause a delayed infusion pump alarm, since calibration is done with 1 infusion line only. It is unknown how much time is needed until the pressure occlusion alarm of the infusion pump is triggered when infusion lines are extended. We therefore measured the time and pressure until an occlusion alarm occurred at different flow rates with one, two, and three infusion lines and a low compliance (LC) infusion line. Our null hypothesis was that the time until an alarm is triggered after occlusion is comparable among the different infusion line extensions.

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Two commercially available infusion pumps of the same model (Combimat 2000, Döring, Munich, Germany) containing a 50 mL syringe (OPS Luer Lock, Braun, Melsungen, Germany) were connected with either 1 (150 cm approximately 59 in.), 2 (300 cm approximately 118 in.) or 3 (450 cm approximately 177 in.) infusion lines (Injectomat line, Fresenius Kabi, Bad Homburg, Germany) or a single 400 cm (approximately 157 in.) spiral nonkinking LC infusion line (IMF, Luedenscheid, Germany). Three different infusion rates were then chosen to simulate infusion of propofol (50 mL/h), remifentanil (20 mL/h), and a vasopressor (5 mL/h). The pressure alarm level of the infusion pumps was set at 1000 Mbar, as recommended by the manufacturer. The infusion pump syringe and infusion lines were filled with normal saline; special care was taken to evacuate all air bubbles; subsequently, the syringe was inserted into the

infusion pump. The infusion pump was then randomly started at either 5, 20 or 50 mL/h, respectively. After a running time of 60 s, the end of the infusion line was occluded by turning a stopcock. To measure the pressure change in the infusion line, the line was attached to a pressure sensor (Validyne DP15–48, Northridge, CA). The time until an occlusion alarm activation was measured for each infusion line extension, infusion rate and type of infusion line and was recorded with a data acquisition system (DAQPad-6020E, National Instruments, Austin, TX). Each setting was measured five times. Results were analyzed using the paired *t* -test, comparing the LC line, 2 lines and 3 lines each with the 1 line setting. All data are given as mean ± sd. *P* values <0.05 were considered statistically significant.

RESULTS

In both infusion pumps, the single infusion line resulted in significantly (*P* = 0.01 and *P* = 0.001) earlier pressure occlusion alarms when compared with 3 connected infusion lines at 5 mL/h (Fig. 1). In all cases, the single LC line, which was almost as long as the 3 serial lines, resulted in occlusion alarm times which were similar to the single normal compliance line. The pressure level triggering an alarm ranged in both infusion pumps between about 900 and 1100 Mbar except for the second infusion pump at 5 mL/h and 3 infusion line extensions (1398 ± 121 Mbar); (Table 1).

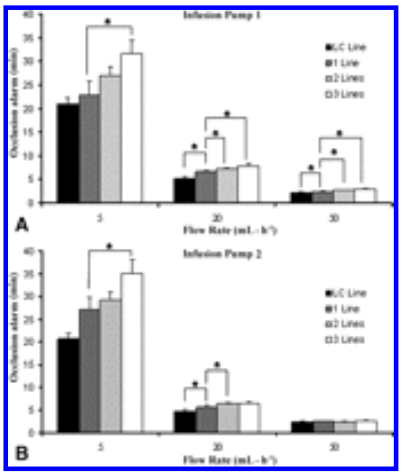

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Figure 1. Occlusion alarm times (min) of 2 different infusion pump systems (A, B) of the same model at flow rates of 5, 20, and 50 mL/h with 1 (1 Line), 2 (2 Lines), 3 infusion lines (3 Lines) and with a low compliance (LC Line) infusion line. Values are given as means ± sd. *Indicates statistical significance (*P* < 0.05) compared to occlusion alarm time with 1 infusion line.

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Table 1. Pressure Occlusion Alarms (Mbar) of two Different Infusion Pumps of the Same Model at Flow Rates of 5, 20, and 50 mL/h with 1 (1 Line), 2 (2 Lines), 3 Infusion Lines (3 Lines) and with a Low Compliance (LC Line) Infusion Line

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Since an occlusion alarm may take up to about 35 min at low (5 mL/h) flow rates and multiple extended infusion lines, pharmacological support of unstable patients in a MRI suite, where multiple extensions with at least 3 infusion lines are required, may be simply inadequate. For example, many vasopressor solutions are infused at low flow rates as simulated by our 5 mL/h setting; this may potentially result in harm when caring for intensive care unit patients. Our results may explain some of the arterial blood pressure instability that occurs while caring for patients receiving vasopressor infusions for diagnostic procedures. So far, the issue of a delayed occlusion alarm was mainly recognized by pediatric intensivists caring for children requiring vasopressor infusions[4–7] but may have been under-estimated in the growing field of anesthesia outside the core operating rooms, where infusion lines are frequently extended to a degree that warrants much more attention. Although awareness may be likely if an anesthetic agent is not infused for a prolonged time, hypnotic drugs, such as propofol, are usually infused at higher rates, which would produce a pressure occlusion alarm within about 5 min according to our data. Since vasopressor infusions are typically infused at lower flow rates, unrecognized infusion line occlusion leading to hypotension may be a bigger problem than awareness.

While multiple connected infusion lines result in later alarm triggering, infusion lines with a LC may produce faster pressure increases, and therefore faster occlusion alarms, in case of an interrupted infusion due to a closed stopcock. Indeed, in this study, the single LC line was almost as long as the 3 serially connected normal compliance lines, but provided the same occlusion alarm times as the single line. Unfortunately, this strategy did not result in a significant advantage, as our model still yielded about 20 min for a pressure occlusion alarm with a LC line at a flow rate of 5 mL/h. This was still not sufficiently brief to avoid the consequences of an interrupted vasopressor infusion. Our and other data indicate that it may be advisable to increase infusion rates of vasopressors by diluting the given drug[5,8,9] although it should be remembered that the risk of a potential intravascular volume overload of intensive care unit patients or children is a major disadvantage of this strategy. To reduce the risk of infusion line occlusion, it might be helpful to use spiral, nonkinking LC infusion lines. Furthermore, it might be advisable to connect the infusion lines directly to the IV line without using a stopcock, especially when administering vasopressors. Technical improvements concerning less-easily turnable stopcocks may be another possibility for reducing the risk of an accidental occlusion of an infusion line. However, vigilance of anesthesia staff under these circumstances is obviously essential. As other studies demonstrated, by using smaller sized syringes, the compliance of the syringes (10 or 20 instead of 50 mL) can reduce pressure occlusion alarm time significantly.[5,6] It has been postulated that there may be a need for technical improvement of infusion pumps, such as a syringe pressure display with an easily adjustable alarm pressure that can be set close to the actual infusion pressure,[5] which is supported by our results. An infusion pump should be used with the ability to select lower pressure levels for triggering an occlusion alarm, thus reducing the time until the alarm will sound, especially when using multiple infusion lines at low flow infusion rates. Although the impact of infusion line distance is pronounced at 5 mL/h flow this difference in occlusion alarm triggering time almost vanishes with 20 mL/h flow, and is completely absent with 50 mL/h flow. One must therefore be especially vigilant with extended infusion line lengths and low flow (i.e., 5 mL/h) infusions, while there is little concern for a delayed occlusion alarm when infusing with a rate ≥20 mL/h.

There are several limitations of the study that prevent generalizing the results quantitatively to other alarms and infusion arrangements. The data were determined in a laboratory setting only. Typical arrangements of multiple simultaneous infusions with the use of a carrier solution were not tested, which could influence the timing of an occlusion alarm downstream in the carrier infusion line. Also, we used normal saline and not the specific drugs which may influence the compliance in the syringe and the infusion lines as well, especially when blood or colloid solutions are used. Furthermore, we only used one type and size of syringe. Infusion line arrangements that use different pumps, syringes, and infusion lines would be expected to yield different absolute occlusion alarm times than those documented in this study. It is likely, however, that many arrangements will result in significantly prolonged occlusion alarm times especially when low infusion rates are used.

In conclusion, when simulating low flow rate infusions (5 mL/h) as for vasopressor support, occlusion alarm time was critically prolonged by an increased length of infusion lines.

Footnotes

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