Benefits of smart pumps for automated changeovers of vasoactive drug infusion pumps: a quasi-experimental study

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Editor’s key points

- Manual changeover of vasoactive drug infusion pumps (CVIP) frequently lead to haemodynamic instability.
- This study demonstrates that smart pumps allowing automated relays decrease both the haemodynamic incident rate and the nursing time dedicated to CVIP compared with manual ‘Quick Change’ relays.

Background. Manual changeover of vasoactive drug infusion pumps (CVIP) frequently lead to haemodynamic instability. Some of the newest smart pumps allow automated CVIP. The aim of this study was to compare automated CVIP with manual ‘Quick Change’ relays.

Methods. We performed a prospective, quasi-experimental study, in a university-affiliated intensive care unit (ICU). All adult patients receiving continuous i.v. infusion of vasoactive drugs were included. CVIP were successively performed manually (Phase 1) and automatically (Phase 2) during two 6-month periods. The primary endpoint was the frequency of haemodynamic incidents related to the relays, which were defined as variations of mean arterial pressure $\geq 15$ mm Hg or heart rate $\geq 15$ bpm. The secondary endpoints were the nursing time dedicated to relays and the number of interruptions in care because of CVIP. A multivariate mixed effects logistic regression was fitted for analytic analysis.

Results. We studied 1329 relays (Phase 1: 681, Phase 2: 648) from 133 patients (Phase 1: 63, Phase 2: 70). Incidents related to CVIP decreased from 137 (20%) in Phase 1 to 73 (11%) in Phase 2 ($P<0.001$). Automated relays were independently associated with a 49% risk reduction of CVIP-induced incidents (adjusted OR=0.51, 95% confidence interval 0.34–0.77, $P=0.001$). Time dedicated to the relays and the number of interruptions in care were also significantly reduced with automated relays vs manual relays ($P=0.001$).

Conclusions. These results demonstrate the benefits of automated CVIP using smart pumps in limiting the frequency of haemodynamic incidents related to relays and in reducing the nursing workload.

Keywords: care workload; critical care nursing; shock; smart pumps; vasoactive drugs

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Continuous administration of short acting and potent medications, such as vasoactive drugs (i.e. catecholamines), during cardiovascular failure is a major challenge in intensive care units (ICUs).1 In daily clinical practice, vasoactive drugs are administered either with i.v. bag pump systems or syringe pumps. Whatever the device used, flow interruption or undesired bolus doses can severely impact patients. The use of high precision pumps with low compliance infusion devices may prevent most unexpected changes in flow rates during continuous administration of vasoressors and inotropes.2 This is particularly true with syringe pumps as the volumes of the syringes are relatively small in comparison with bags. As a result, they need to be changed frequently which interrupts the drug’s delivery and can lead to haemodynamic instability.2,3 Moreover, this high-risk period may be time-consuming, depending on the methods of relays.

Various techniques have been described for the changeover of vasoactive infusion pumps (CVIP).4 In these methods, the CVIP is ordinarily performed manually, which consumes the nursing staff’s time and could lead to human errors and, therefore, incidents.4 Among the common substitution methods for catecholamines, the ‘Quick Change’ method, which utilizes two
syringe pumps without an overlapping period, seems as safe as other procedures while minimizing haemodynamic incidents and the nursing staff’s workload. We previously demonstrated, according to a quality improvement programme, that the ‘Quick Change’ method was all the more effective as it was strictly standardized. In the past few years, new ‘smart infusion pumps’ have been designed to secure administration of i.v. drugs. Smart pumps devices, linked to the clinical information system, have drug libraries and features including drug/dose calculations and provide point-of-care decision support feedback for overly high or low i.v. infusion rates and doses. Some of the newest smart pumps allow automated syringe relays according to an algorithm derived from the ‘Quick Change’ approach. The ‘relay function’ of these smart pumps, linking two syringes, could limit the interruptions of the flow rate during the CVIP. This programmable method of CVIP may also simplify the work of the bedside nurse.

The objective of the present study was to test the hypothesis that automated relays using smart pumps could limit both haemodynamic incidents and the CVIP-related workload of ICU care providers compared with a standardized ‘Quick Change’ method.

Methods

This study was conducted during routine care in a 15-bed university-affiliated adult medical ICU. Ethical approval was obtained from the ethics committee of the Hospices Civils de Lyon. The Institutional Review Board waived the need for consent given the nature of the study. The study was performed in compliance with the ethical standards detailed in the 1964 Declaration of Helsinki and according to the French laws.

Study design

We performed a prospective quasi-experimental study to evaluate the implementation of an automated method for performing relays of syringes with vasoactive drugs in our ICU, according to a quality improvement programme. During the first 6-month period of the study (Phase 1), all CVIP were performed according to the ‘Quick Change’ method, whereas, automated relays with smart pumps were used during a second 6-month phase (Phase 2). Haemodynamic incidents and workload related to CVIP were measured in both phases. No change in both the nursing staff and in haemodynamic management for cardiovascular dysfunction occurred during the study period.

Patients

We studied CVIP for all adult patients treated for shock with vasoactive drugs (i.e. norepinephrine, dobutamine, or epinephrine) during the study period. Cardiovascular failure was defined by a mean arterial pressure (MAP) < 65 mm Hg, a cardiac output < 2.5 litre min⁻¹ m⁻², or both, with signs of peripheral hypoperfusion despite adequate fluid resuscitation. For these patients, vasoressors, inotropes, or both were required to restore arterial pressure and organ perfusion in accordance with French and international guidelines. Patients were continuously monitored, including continuous invasive arterial pressure.

Administration of the vasoactive drugs

All patients who received continuous administration of vasoactive drugs had a multilumen central venous catheter. The proximal lumen was always dedicated to catecholamines and a three-way stopcock was connected to this lumen to perform CVIP. The vasoactive drug’s syringes were changed because the volumes of infusion were almost depleted or, under local policy, 24 h had lapsed. Fresenius Vial (Module DPS) syringe pumps (Fresenius Kabi/Vial, Brezins, France) were routinely used in our ICU with 60 ml capacity luer lock BD Plastipack syringes (BD Plastipack®, Octeville, France). Syringe pumps were connected to a smart pump infusion workstation, Orchestra® Base Intensive (Fresenius, Brezin, France). For each new patient, the name and weight were stored in the database of the infusion device. The nurses had to specify the name (from a library) and concentration of the vasoactive drug when a full syringe was installed on its holder. If the remaining volume in the syringe was < 2 ml, a pre-alarm informed nurses that the infusion was ending.

Phase 1: manual ‘Quick Change’ relays

During a 6-month period, the CVIP were performed in accordance with our routine clinical practices. Our standardized protocol was continuously available in a specific form in the ICU and all the nurses received refresher courses (1-month period) before the beginning of the study. As previously described, the ‘Quick Change’ method consisted of loading the new infusion with a new line into a new syringe pump, containing the drug at the same concentration, and priming the line when the running infusion was about to end. Both syringes were maintained at bed height. Nurses started the (unconnected) pump and chose a high flow rate until a decrease of vasoactive drug appeared at the end of the line, to avoid a start-up delay. Next, they programmed the pump to the same rate and setting as the previous infusion. Then, they removed the cap from the spare port of the three-way stopcock and connected it to the new infusion pump. They next turned the three-way stopcock on to the new infusion, which closed the lumen of the old infusion. Finally, they disconnected the old infusion and put a cap on the spare port.

Phase 2: automated relays

After Phase 1, during a 1-month period, each nurse received a 1-day training course including practical work, to learn the automated two-channel relay. After this training period, all the CVIP were performed automatically over a 6-month period. This modality of automated relay, provided by the smart pump infusion workstation Orchestra® Base Intensive (Fresenius Kabi/Vial, Brezins, France), consisted of two associated channels, which infused the drug one after the other at the same dose. Briefly, up to 4 h before the end of the old infusion, nurses had to select the two-channel relay function of the smart pump and to install the new full syringe (containing...
the same drug at the same concentration) on an available pump. Before connecting to the patient, the new infusion line was purged of air from the connector. The old syringe and the new infusion were then connected with a three-way stopcock. After that, the old and the new syringe pumps were selected by the nurses and associated for the incoming relay. An alarm sounded to inform nurses of the relay’s execution.

Measurements

Baseline characteristics of patients

Data on gender, age, preexisting underlying diseases according to the McCabe and Jackson scale, type of admission (i.e. medical or surgical) and shock, number of organ failures as assessed by the Organ Dysfunction, Infection score, or both (ODIN), severity of illness according to the Sequential Organ Failure Assessment score (SOFA) and the Simplified Acute Physiology Score II (SAPS II), length of stay in the ICU, and mortality were collected.

Haemodynamic incidents

Heart rate (HR) and MAP were continuously recorded on a personal computer-based data acquisition system supported by Intellivue Clinical Information Portfolio (ICIP) software (Philips Medical Systems, The Netherlands).

Characteristics of the syringe pumps with vasoactive drugs

For each catecholamine, doses and flow rates were continuously monitored and stored every 5 min on a personal computer-based data acquisition system supported by Intellivue Clinical Information Portfolio (ICIP) software (Philips Medical Systems, The Netherlands).

Time dedicated to CVIP

Nurses recorded themselves (using a chronometer) the time required to manage CVIP. This time included the placement of the full syringe on the infusion pump, purge of the connector tube, connection to the three-way stopcock, smart pump infusion workstation programming, and the management of possible CVIP incidents (attendance of the nurse at bedside). Moreover, all nursing and medical tasks interrupted because of the relay were recorded. These interruptions were defined by the need for the caregiver to go to the bedside for managing CVIP (or CVIP-related incidents) whereas he was treating another patient.

Statistical analysis

Assuming a CVIP-related incident frequency of 20% (ΔMAP ≥ 15 mm Hg or ΔHR ≥ 15 bpm) with the ‘Quick Change’ method, we calculated that at least 1172 CVIP events would be required for the study to have 90% power to detect a 35% reduction in the relative risk with a two-sided alpha level of 5%. Data are expressed as counts and proportions or as the mean [standard deviation (SD)], as appropriate. Comparisons of categorical variables were performed using two-sided Fisher’s exact test. Continuous data were compared using the Mann–Whitney U-test or Friedman’s test if appropriate.

A mixed effects logistic regression was then fitted to assess factors associated with CVIP-induced haemodynamic incidents. This model is derived from the generalized linear mixed model and it permitted to estimate both fixed effects (i.e. factors related to the syringe relay) and random effects (i.e. related to the patient). The dependent variable was CVIP-related incident, as defined above. The model had also two levels: changeover characteristics (Level 1) and patient characteristics (Level 2). The exposure of interest was the method of syringe relay (manual ‘Quick Change’ during Phase 1 vs automated relay during Phase 2). The potential confounders related to changeover characteristics were the type of vasoactive drug, the dose, and the flow rate. The potential confounders related to patient characteristics were: gender, age, type of shock, number of organ failures, SOFA score, and SAPS II. Covariates with a $P < 0.10$ after univariate analysis were entered in the first multivariate model; type of vasoactive drug, dose, and flow rate were forced in the multivariate analysis. Models were then compared using a backward selection with the Wald test. Stata 11 (StataCorp. 2009. Stata Statistical Software: Release 11. College Station, TX, USA: StataCorp LP) was used for analysis. Statistical significance was defined as a value of $P < 0.05$; all the tests were two-tailed.

Results

Over the study period, we studied CVIP for 133 ICU patients: 63 in Phase 1 and 70 in Phase 2. No patient was common to both phases of the study. Baseline characteristics of patients are presented in Table 1 and did not significantly differ between groups. All the patients had a cardiovascular failure and 120 (90%) required mechanical ventilation. Of those, 100 (75%) were admitted to the ICU for septic shock and 121 (91%) received norepinephrine. Patients received vasoactive drugs for 6 (2) days in Phase 1 vs 6 (5) days in Phase 2 ($P = \text{ns}$).

For these patients, 1329 CVIP were evaluated: 681 in Phase 1 and 648 in Phase 2 with a similar number of CVIP per patient in both phases [12 (20) and 10 (8), respectively; $P = \text{ns}$]. Relays of syringes with norepinephrine were the most frequent in both phases with a total of 1019 CVIP (77%) for this catecholamine (Table 2). However, the distribution of CVIP was significantly different among phases ($P < 0.001$) with more changeovers of norepinephrine and less relays of dobutamine in Phase 2 (Table 2). Mean doses and flow rates of norepinephrine were also significantly higher in Phase 2 than in Phase 1 ($P < 0.001$), whereas they were significantly lower ($P < 0.001$) with dobutamine in Phase 2 (Table 2). Nevertheless, dilutions of the catecholamines in the syringes were similar in both phases ($P = \text{ns}$; data not shown).

We recorded a total of 234 CVIP-induced haemodynamic incidents (i.e. variations of MAP > 15 mm Hg, HR > 15 bpm, or both related to the relay) during the study: 151 (22%) in
Phase 1 and 83 (13%) in Phase 2 (P < 0.01). As given in Table 3, the number of CVIP with at least one haemodynamic incident significantly decreased from 137 (20%) in Phase 1 to 73 (11%) in Phase 2 (P < 0.001). The nature of incidents was similar (P = ns) between phases. Among the 146 arterial pressure and 88 HR incidents observed in the overall study, 93 were hypertensions (64%) and 44 were tachycardias (50%), respectively. As expected, incidents from the relays of norepinephrine (i.e. variations of MAP) and dobutamine (i.e. variations of HR) were significantly prevented in Phase 2 (Table 3). In addition, the number of severe haemodynamic incidents (i.e. variation of MAP > 30 mm Hg or HR > 30 bpm) was significantly lower in Phase 2 than in Phase 1: 16 (2.5%) vs 34 (5.0%). Variations in MAP > 30 mm Hg were observed during 18 relays of syringes with norepinephrine (3.7%) in Phase 1 vs 9 (1.7%) in Phase 2; variations in HR > 30 bpm occurred eight times (4.4%) in Phase 1 and only once (1.2%) in Phase 2 (P < 0.05). There were no fatal events related to CVIP observed during this study.

After univariate mixed effects logistic regression analysis, automated syringe relays were associated with a 54% decreased risk of CVIP-induced haemodynamic incidents, when compared with manual ‘Quick Change’ relays. (Crude Odds ratio (OR) = 0.46; 95% confidence interval (95% CI) 0.31–0.69, P < 0.0001). After multivariate analysis, automated relays were associated with a 49% decreased risk of CVIP-related incidents, compared with manual syringe relays (adjusted OR = 0.51, 95% CI 0.34–0.77, P = 0.001), independently of type of vasoactive drug, dose, flow rate, patient age, and SOFA score.

The nursing time dedicated to CVIP was also significantly (P < 0.001) reduced by 54% in Phase 2 compared with Phase 1 (Table 4). This beneficial effect was observed for each catecholamine (Table 4). In addition, as given in Table 5, the number of interruptions in care (for nurses or intensivists) because of CVIP decreased significantly from 148 (22%) in Phase 1 to 25 (3.8%) in Phase 2 (P < 0.001).

Discussion

In this study, we demonstrate, for the first time, that smart pumps allowing automated relays decrease both the haemodynamic incident rate and the nursing time dedicated to CVIP, improving the organization of care in the ICU.

In patients with shock, the major aim of haemodynamic therapy is to restore and maintain cardiac output and perfusion pressure. Patients who do not respond to initial fluid resuscitation require vasopressors, inotropics, or both to achieve these goals. These potent drugs have a very short half-life and a narrow therapeutic index. For these reasons, slight variations in doses could induce life-threatening variations in arterial pressure or cardiac rhythm. Consequently, it is a challenge to maintain the continuity of the perfusion during CVIP and, therefore, the haemodynamic stability. Despite this being a frequent challenge in ICU routine care, there are few studies published on this topic. Studies, from our group and others, have previously reported rates of haemodynamic incidents related to CVIP, which depending on the definition

| Phase 1 | Phase 2 | P-value
<table>
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<tbody>
<tr>
<td>Male sex*</td>
<td>42 (67)</td>
<td>47 (67)</td>
</tr>
<tr>
<td>Mean age (years)*</td>
<td>66 (14)</td>
<td>61 (16)</td>
</tr>
<tr>
<td>McCabe scale*</td>
<td>21 (33)</td>
<td>29 (46)</td>
</tr>
<tr>
<td>No fatal disease*</td>
<td>13 (21)</td>
<td>22 (31)</td>
</tr>
</tbody>
</table>

Table 1 Baseline characteristics of patients. SOFA, Sepsis-related Organ Failure Assessment; SAPS II, Simplified Acute Physiology Score II. *Data are expressed as the number (%) of patients. †Data are expressed as the mean (sd).
used, varies from 6 to 38%. To our knowledge, the present work, studying >1000 relays, is the largest one evaluating CVIP methods and related incidents. We still observed a high rate of incidents (≈20%) using a manual procedure for the CVIP. We defined haemodynamic incidents as a variation of in MAP >15 mm Hg or in HR >15 bpm, as such variations may have an impact on patients’ safety. The majority of these incidents were arterial pressure variations, which is directly linked with the proportion of our patients with septic shock treated with vasopressors. Automatization of the procedure, using the relay function of smart pumps, allowed the rate of these cardiovascular events to be reduced by a half in this study. We performed a quasi-experimental study rather than a randomized trial. Given the nature of the study, we recorded some imbalance in patients’ and CVIPs’ characteristics before and after implementation of automated relays. However, the decrease in CVIP-related incidents remained very significant after controlling for confounding factors. We cannot exclude that some unmeasured factors might have occurred coincident with the implementation of the automated method. Yet, the study was of brief duration and only minor changes have occurred with respect to both healthcare team and clinical practices. While achieving haemodynamic stability during CVIP is an objective itself, the positive effects we observed in improving quality care are clinically relevant. As in previous reports, this finding emphasizes the importance of the relay procedure for limiting haemodynamic consequences during care in the ICU.

Plastic syringes filled with vasoactive drugs are routinely used in both the ICU and operating rooms. The limited capacity of the syringes requires CVIP on a regular basis to ensure a continuous supply of medication. Several methods using two syringe pumps have been described for performing CVIP, with or without an overlapping period (named ‘Double Pumping’ and ‘Quick Change’, respectively). Although more time-consuming, methods including an overlapping period could be, in theory, more effective in preventing haemodynamic incidents. However, three clinical studies comparing both methods failed to determine the superiority of the ‘Double Pumping’. As a result, and in the absence of guidelines now available, the ‘Quick Change’ method appeared to be the best compromise between simplicity and efficacy, while limiting nurses’ workloads. In the present study, there were still a significant number of haemodynamic incidents related to CVIP when using a standardized manual ‘Quick Change’ method. As expected, automated CVIP provided by the smart pumps significantly limited these cardiovascular events. The main strength of this work was to control, in addition to patients’ characteristics, potential confounders related to changeovers (i.e. the type of vasoactive drug, the dose, and the flow rate). Interestingly, the algorithm of the smart pump’s relay function was also very close to the manual

### Table 3

<table>
<thead>
<tr>
<th></th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>P-value</th>
</tr>
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<tbody>
<tr>
<td>Norepinephrine</td>
<td>n=483</td>
<td>n=536</td>
<td></td>
</tr>
<tr>
<td>ΔMAP &gt;15 mm Hg</td>
<td>76 (16)</td>
<td>51 (10)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ΔHR &gt;15 bpm</td>
<td>31 (6)</td>
<td>21 (4)</td>
<td>0.09</td>
</tr>
<tr>
<td>ΔHR or ΔMAP</td>
<td>96 (20)</td>
<td>64 (12)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>n=183</td>
<td>n=83</td>
<td></td>
</tr>
<tr>
<td>ΔMAP &gt;15 mm Hg</td>
<td>10 (5)</td>
<td>2 (2)</td>
<td>0.35</td>
</tr>
<tr>
<td>ΔHR &gt;15 bpm</td>
<td>29 (16)</td>
<td>5 (6)</td>
<td>0.03</td>
</tr>
<tr>
<td>ΔHR or ΔMAP</td>
<td>37 (20)</td>
<td>6 (7)</td>
<td>0.01</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>n=15</td>
<td>n=29</td>
<td></td>
</tr>
<tr>
<td>ΔMAP &gt;15 mm Hg</td>
<td>4 (27)</td>
<td>3 (10)</td>
<td>0.21</td>
</tr>
<tr>
<td>ΔHR &gt;15 bpm</td>
<td>1 (7)</td>
<td>1 (3)</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>ΔHR or ΔMAP</td>
<td>4 (27)</td>
<td>3 (10)</td>
<td>0.21</td>
</tr>
<tr>
<td>Total</td>
<td>n=681</td>
<td>n=648</td>
<td></td>
</tr>
<tr>
<td>ΔMAP &gt;15 mm Hg</td>
<td>90 (13)</td>
<td>56 (9)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ΔHR &gt;15 bpm</td>
<td>61 (9)</td>
<td>27 (4)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ΔHR or ΔMAP</td>
<td>137 (20)</td>
<td>73 (11)</td>
<td>&lt;0.001</td>
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</table>

### Table 4

<table>
<thead>
<tr>
<th></th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norepinephrine</td>
<td>318 (209)</td>
<td>131 (71)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>282 (90)</td>
<td>138 (62)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>387 (331)</td>
<td>123 (39)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>All catecholamines</td>
<td>310 (189)</td>
<td>131 (69)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

### Table 5

<table>
<thead>
<tr>
<th></th>
<th>Nurses</th>
<th>Intensivists</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phase 1</td>
<td>Phase 2</td>
</tr>
<tr>
<td>Norepinephrine</td>
<td>85/483 (18)</td>
<td>9/536 (2)</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>21/183 (11)</td>
<td>1/83 (1)</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>0/15 (0)</td>
<td>0/29 (0)</td>
</tr>
<tr>
<td>Total</td>
<td>106/681 (16)</td>
<td>10/648 (2)</td>
</tr>
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</table>
‘Quick Change’ method. Therefore, we suppose the benefit of the relay function, available on the latest generations of smart pumps, results primarily from a better standardization because of automation of the procedure.

For several years, syringe infusion devices, now referred to as smart pumps, have been manufactured with software. 26 Henceforth, these ‘intelligent infusion devices’ are widely available in the ICU. 6 27 To reduce medication errors, most smart pumps use hospital-specific drug libraries that define both upper and lower dosing limits for the drug being administered and provide dose calculations. 26 Patients treated for a shock should particularly benefit from these new technologies because vasoactive drugs (with narrow safety margins) need individualized weight-based dose calculations. However, two large negative studies have evaluated the potential interest of using smart pumps in ICU. 6 27 To our knowledge, no previous study has specifically evaluated whether smart pumps could improve vasoactive drug administration and CVIP. In this work, we only examined the automated relay function of our smart pumps, showing a haemodynamic benefit during CVIP. The other potential advantages of the basic functions (i.e. drug library, dose calculations, etc.) were not specifically evaluated in this work because they were used in a similar way in both phases. In addition, for the first time, we demonstrated that smart pumps with expanded capabilities could also improve patient safety while limiting the workload of nurses in the ICU.

Among ICU patients, those treated with vasoactive drugs are usually the most time-consuming for the whole staff. 28 29 Part of the nursing time is dedicated to vasoactive therapy, including management of the CVIP. In the present study, the nursing time related to the relays of syringes was reduced by more than half when automated CVIP were used. Several explanations could explain our positive results. First, nurses did not necessarily spend time monitoring the relay at bedside during the automated process. Secondly, reduction of haemodynamic incidents by using automated relays led to fewer reinterventions to manage the CVIP and, therefore, to a decrease in the time dedicated to this care. In practice, based on the experience of our nurse staff, being familiar with the smart pump technology, it must be noted that the automated CVIP programming did not take more time than selecting a new syringe pump for the manual method. In addition, as the automated CVIP could be programmed several hours before the end of the syringe, nurses could anticipate the relay when they were at bedside and when they were not overloaded with work. Thus, automated relays provided more time to calmly attend to this care. Moreover, the automated relay occurred despite the availability of the healthcare workers. Consequently, the nurses only had to be interrupted when they had to manage a problem related to the CVIP. As a result, the automated method decreased the number of nursing task interruptions by ~90%. We also showed that intensivists were less interrupted during their work to manage CVIP-related incidents.

In summary, we report that smart pumps allowing automated CVIP could be timesaving in the ICU and could contribute to better work-time organization.

In conclusion, our study demonstrates for the first time, that smart pumps allowing automated relays of vasoactive drug infusion pumps reduce the rate of haemodynamic incidents by half and also improve the quality and the organization of care in the ICU by decreasing the number of nursing and medical tasks interrupted and reducing the time dedicated to this current high-risk procedure.

Authors’ contributions

M.C. and L.A. conceived the study, created its design, performed the univariate statistical analysis and interpretation of data, and drafted the manuscript. T.B., P.V., and L.A. performed the multivariate statistical analysis. R.H., J.M.R., D.R., B.C., A.M., S.C., P.S., and M.L. participated in nurses’ training for the protocol and in collecting the data. All authors read and approved the final manuscript.

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Declaration of interest

L.A. has received research support from Fresenius Vial. Fresenius Vial had no role in the study design, data collection, data analysis, data interpretation, or writing of the report. All other authors declare that they have no conflict of interest.

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