



Advantages in Management and Remote Monitoring of Intravenous Therapy: Exploratory Survey and Economic Evaluation of Gravity-Based Infusions in Finland

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ABSTRACT

Introduction: Intravenous infusion therapy is a common and challenging invasive treatment procedure in hospital wards. Administration mistakes can have serious, even life-threatening, consequences. The Monidor solution was developed to help nurses administer gravity-based infusions and monitor them remotely, to avoid complications and reduce workload. Its real-world effects and economic consequences were unknown.

Methods: An exploratory survey was carried out to estimate the potential impact of the Monidor solution on events and nurse time use. At the end of their shift, nurses estimated effects in terms of routine room visits avoided, prevention of complications, and impact on nurse time requirements. Linear regression was applied to estimate predictors of time freed. A health economic model was developed to evaluate economic consequences and to calculate the net return on investment for a hypothetical

hospital ward. A 1-month time horizon was used, and discounting was not applied.

Results: A total of 216 responses were obtained from 6 Finnish hospitals, from a total of 15 wards, and 56.3% of nurses found that the Monidor solution freed nurse time, while < 3.5% experienced additional time requirements. Per nurse shift, the Monidor solution avoided on average 2.064 routine room visits, helped detect end of infusion 1.340 times, and led to 5.045 min of time freed. One routine visit avoided was associated with 2.453 min of time freed in the linear regression. In the conservative setting, the freed monthly capacity in the hypothetical ward amounted to €1270.90 per month (year 2021), yielding a return on investment of 2.63. Uncertainty of linear regression coefficient values was identified as a driver of uncertainty in sensitivity analysis, with return on investment ranging from 1.55 to 3.71.

Conclusions: The study demonstrated that management and remote monitoring with the Monidor solution frees nurse time and reduces routine activities associated with gravity-based intravenous infusions. These findings could be confirmed in a comparative empirical study.

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PLAIN LANGUAGE SUMMARY

In hospitals, patients often receive fluids intravenously. These fluids enter the blood circulation directly, and their incorrect administration (too much or too little, too slow or too fast) can have serious and potentially life-threatening consequences. The Monidor solution aims to improve administration of intravenous fluids. It consists of two components: a mobile app for remote monitoring and a meter for bedside management. This study aimed to estimate the impact of the Monidor solution on administration of intravenous fluids and to assess how the Monidor solution would affect costs. Among the factors considered were the price of the devices, nurse time freed, and prevention of complications with the intravenous therapies. The data were collected via questionnaires from nurses from 15 wards in 6 Finnish hospitals. According to the responses and a health economic model designed for this study, the Monidor solution freed capacity with a value of €1270.90 per month. When considering the local cost of the Monidor solution, the return on investment was positive. In summary, the Monidor solution is cost-effective; routine room visits by nurses were avoided, problems with infusions were detected earlier, and nurse time was freed. These findings could be confirmed in a larger study.

Keywords: Cost Analysis; Digitalisation; eHealth; Error Detection; Intravenous Therapy; Material Savings; Nursing; Return on Investment; Time Freed; Workload

Key Summary Points

Why carry out this study?

Many challenges of gravity-based intravenous therapy could be overcome by use of the Monidor solution for infusion management and remote monitoring

We carried out economic evaluation of the Monidor solution in Finland based on data and modelling, and asked the question, “Is it worth the investment?”

What was learned from this study?

Nurses in six Finnish hospitals evaluated the effect of the Monidor solution on patient safety and time requirements in survey.

With the Monidor solution, routine room visits were avoided and problems with infusions detected earlier. This freed nurse time and saved materials

In typical wards, the capacity freed through use of the Monidor solution clearly exceeded its costs, and its return on investment was positive

INTRODUCTION

Intravenous (IV) infusion therapy is one of the most common invasive treatment procedures in hospital wards, and roughly 80–90% of inpatients receive IV therapy in some form [1–3]. Based on the market shares of infusion sets in Europe, approximately two-thirds of all IV infusions are delivered gravity-based and adjusted by roller clamp without an infusion pump or other electronic controller [4].

Infusion rate alteration in IV fluids can lead to undesirable changes in homeostasis [5]. Especially elderly and critically ill patients are prone to serious complications, such as pulmonary oedema, hyponatraemia, prolonged length of hospital stay (LOS) or even death [5, 6]. Inappropriate IV therapy and fluid retention are well-recognized aetiologies for such complications [7]. Hyponatraemia may prolong LOS, increase the risk of readmission to the hospital, and is associated with a marked economic burden [8]. Numerous studies (e.g. [6, 9, 10]) have shown a great impact of optimal fluid balance on the LOS, complications,

mortality rate, or total costs in the different patient groups.

Another challenge in IV therapy can be the beeping tone of infusion pumps, which may disturb patients and incur additional nurse visits to the patient room [11, 12]. Although critical alarms are hard to filter from non-urgent ones [11], and the number of alarms has increased exponentially [12], intravenous pump alarms need to be responded to accurately and timely to maintain infusion continuity [11]. Even though inconveniences and the potential for serious and even life-threatening complications due to inaccurate IV therapy are well recognized, the clinical practice of delivering IV fluids has remained unchanged for decades. Errors in administering prescribed IV fluids, such as incorrect infusion rate or unprescribed dosing, are well documented (e.g., [13, 14]). However, IV infusion-related complications are an overlooked problem [15, 16]. Only 26 percent of IV fluid bags given in acute medical wards were given at the prescribed rate, while the use of a metered pump increased accuracy of the IV therapy [17]. However, infusion errors associated with IV pumps occur frequently [2], and nurses have found it challenging to maintain a stable flow rate and ensure sufficient IV fluid administration [18].

To ensure the correct IV infusion rate, nurses must visit rooms often to carry out visual checks or use an infusion pump, which is time consuming, associated with beeping disturbance, and can increase cognitive stress. [11] Michard [19] identified a few technical solutions and mobile applications developed to improve quality of care and decrease the routine work of nurses. IV infusion control devices can prevent medication administration errors [14]. Remote monitoring of infusion therapies in hospital wards may hypothetically eliminate unnecessary routine tasks, avoid beeping disturbance, reduce the number of nurse walking steps, and, hence, lessen the nursing workload required for safe, efficacious and quiet delivery of IV infusions.

We are unaware of any publications addressing real-world outcomes or the cost-effectiveness of remote monitoring of IV infusion therapies in general hospital wards. The roll-out

of the Monidor solution in hospital departments around Finland provided an opportunity to study its impact on IV infusion-related events and nurse time. We hypothesised that this would lead to material savings through events avoided and nurse time freed for other acute care activities.

OBJECTIVES

The aim of the study was to estimate the effects and economic impact of using the Monidor solution in controlled gravity-based IV infusion care (management and remote monitoring) in the Finnish hospital setting.

METHODS

Intervention

The Monidor solution is a medical device for remote IV infusion management that consists of two CE-compliant components: IV Screen™, which is a software application, and Monidrop® (both Monidor Oy, Oulu, Finland), a compact infusion meter for gravity-based IV therapy. The Monidrop device assists the user to adjust the required infusion rate with the roller clamp, while the remote monitoring software application displays the status of infusions for every Monidrop device in use. The measurement of infusion flow is carried out by an optical sensor counting drops over time, and this information is used to calculate the flow rate, total volume and time duration. Due to the remote monitoring software application, there is no real need for the disturbing beeping systems. [20]

A typical Monidor setup in a hospital department with approximately 30 beds consists of 5–10 Monidrop devices with a charging station, 1–2 tablets or screens in the nursing room for remote monitoring, and, optionally, the IV Screen application for hospital smartphones. These components are shown in Fig. 1.

User training of the Monidor solution medical device is provided for nurses in small groups of 3–5 people, and includes an introduction, the intended use, example use cases, and hands-on



Fig. 1 Components of the Monidor solution

training. Every session typically takes 30 min and can be carried out face-to-face or using video material for self-training.

Data Collection

As a part of the Monidor solution commissioning, we carried out explorative questionnaire surveys to follow-up on nurses using the Monidor solution. As the primary aims of the Monidor solution are to improve IV therapy workflow, enable easier adjustment of infusion rate and remote monitoring, mitigate the risk of mistakes, and shorten the time to error detection, questions addressing these topics were asked. Use of the Monidor solution was expected to have practical implications consisting of reduced numbers of routine checks in both normal and isolation rooms and earlier detection of impending IV-line blockage, end of infusion, and other irregularities. Nurses were asked to quantify these effects.

Nurses answered the product evaluation questionnaire right after their daytime, evening, or night shift. These surveys were implemented after 5–6 weeks' use of the system to guarantee correct operation. The duration of each questionnaire survey was 4–8 days depending on the study site. Data were collected from 15 departments in 6 Finnish hospitals, listed in the Supplementary Appendix. Questionnaire topics were IV infusion amounts,

and how many of them with Monidor, routine room visits avoided to normal or isolation rooms, end of infusion, risk of line blockage, unusual speed, or other problem detected. Additionally, the nurses were asked how the use of the Monidor solution impacted (reduced or increased) their working time. The questionnaire is available from the authors on request.

We complied with the relevant ethical guidelines, and the study was performed in accordance with the Helsinki Declaration of 1964 and its later amendments. This survey study was not preregistered because it was exploratory and based on aggregate expert assessments, i.e. nurses assessed the use and impact of a medical device-regulated tool and software in a survey after they had used it. The nurses would have used the CE-marked tool and CE-marked software in any case in their work.

Nurses were incentivised to participate in the survey, but participation was totally voluntary. They were informed about the survey study and gave their consent when they answered.

The study and data collection were non-interventional, non-medical, and carried out for product evaluation by caregivers. Patients were not involved or impacted by the questions and patient-level data were not shared. The CE-marked medical device was already in use. There was no medical study or trial setting involved based on the Finnish law for medical research

(9.4.1999/488). Consequently, ethics committee approval was not needed.

A frequency of less than five survey responders was stated with less than (<) 5 or respective percentage marking. The dataset is not available because consent for such data sharing was not obtained.

Statistical Analysis

In the first step, questionnaire data were managed by removing the non-respondents (i.e. when all responses were left at their default values). Additionally, responses from three wards had to be discarded because of unreliable wireless network connectivity in the ward, which prevented the remote monitoring devices from working as intended and distorted the data of these three wards.

Next, for respondents who estimated that the use of the Monidor solution freed time but who were unable to provide a numerical estimate of the amount of time freed, their time freed in minutes was imputed. To provide robustness against outliers and conservative estimates, imputation used the median value of those respondents who experienced time freed and did provide a numerical estimate for these, and likewise for respondents experiencing increased time requirements but unable to estimate this numerically.

For descriptive statistics, the unweighted means, standard deviations, and interquartile ranges for each of the questionnaire items (events per nurse shift) are reported. For the statistical analyses, the respondents were weighted inverse proportionally to the number of respondents in that ward, such that each ward was allocated the same weight.

Two statistical analyses were carried out: (1) weighted means (events per shift) by type of shift (morning, evening, night), and (2) a linear regression model to explain the perceived overall time freed per nurse shift by the explanatory questionnaire topics. The Akaike information criterion (AIC) was used to consecutively select more elaborate regressions, which differed in whether normal and isolation rooms were combined into one variable and

which of the detected problems were included as separate variables. All statistical analyses were carried out in R version 4.1.1 [21].

Economic Analysis

The patients-intervention-comparator-outcomes-settings-time-effects-perspective-sensitivity analysis (PICOSTEPS) framework was used to provide a concise summary of the economic evaluation [22] (Table 1).

For the economic analysis, the estimated events per nurse shift were extrapolated to monthly events, using a representative hypothetical department staffed by 3 morning, 3 evening, and 2 night nurse shifts, and an average month length of 30.438 days. Using year 2021 euros, the resources associated with a

Table 1 PICOSTEPS overview of the economic analysis

Domain	Details
Patients	Individuals receiving infusions in the hospital department
Intervention	Monidor solution-controlled infusion management and remote monitoring
Comparator	Standard gravity-based infusion management
Outcomes	Potentially freed capacity and economic impact (material savings, time freed, return on investment)
Setting	Comparison based on survey data and modelling for economic evaluation
Time	One-month time horizon, year 2021 € valued costs
Effects	Changes in the number of events and nurse time
Perspective	Service provider
Sensitivity analyses	One-way sensitivity analyses of key model inputs ($\pm 10.0\%$) and regression coefficients (95.0% confidence interval limits)

routine visit avoided to an isolation room were set to €4.52 (protective coat, mask, and nitrile gloves [23]), and an early enough detection of risk of blockage before, e.g. cannula occlusion was assigned a resource cost saving of €2.00 for the cannula, which are both likely underestimates [24]. Prevention or early detection of other problems was conservatively assumed to have no economic value. Freed nurse time was predicted using the linear regression model and costed conservatively at €28.40 per hour (labour costs, human health and social work activities; Statistics Finland [25]).

Net return on investment (ROI) was estimated using the total cost of the Monidor solution in a hypothetical hospital ward with 10 devices (approximately €350.00 per month), and calculated as the net capacity freed divided by the investment cost. Results are presented undiscounted.

To evaluate uncertainty, individual inputs ($\pm 10.0\%$) and regression coefficients (95.0% confidence interval limits) were varied one by one in one-way sensitivity analyses, and respective net ROIs were calculated. The 10 inputs with the largest impacts on net ROI were identified, and the results are presented in a tornado diagram.

In addition, in a scenario analysis, we modified the cost savings associated with early enough detection of risk of blockage to the most affordable official Finnish hospital tariff for an anaesthesiologist placing a new venous cannula (Kainuu hospital district price list 2021: €216.00), and assumed that this early detection prevents a new cannulation in 23.4% of cases noted with the Monidor solution (that is, 23.4% was the risk of occlusion or infiltration observed in a recent sample of 11,830 catheters [24]). The material cost of €2.00 was excluded from the cannulas set by anaesthesiologist to avoid double counting.

RESULTS

In total, 216 questionnaire responses were collected from 15 wards shown in the Appendix. Based on crude assessment, the response rates exceeded 50.0%. These hospital wards cover

Finland geographically and can be considered a representative sample of IV hospital care in Finland. After deleting responses from three wards with network connectivity problems, and additionally 11 blank responses, 141 survey responses were analysed for effects: 59 morning (41.8%), 42 evening (29.8%), and 40 night shifts (28.4%).

A total of 79 respondents (56.3%) answered that the use of the Monidor solution freed nurse time, and fewer than five respondents (< 3.5%) stated that it required additional nurse time. The median values used for imputing 7 blank responses (5.0%) of the time freed and less than five (< 3.5%) blank responses of additional time required were 10.000 min freed and 20.000 min additional time, respectively. The descriptive statistics (results per nurse shift) are shown in Table 2. Weighted means by shift type are shown in Table 6 in the Supplementary Appendix.

The best-fitting linear regression model explaining perceived time freed was a model

Table 2 Survey responses

Outcome per nurse shift (number)	Mean	SD	Range	IQR
All IV infusions	2.267	1.159	1, 5	1, 3
Monidor solution used	1.660	0.893	1, 5	1, 2
Effects of the Monidor solution				
Routine visits avoided	2.064	1.385	0, 8	1, 3
Normal rooms	1.489	1.240	0, 4	0, 2
Isolation rooms	0.582	0.950	0, 4	0, 1
End of infusion detected	1.340	1.054	0, 4	1, 2
Unusual speed detected	1.305	1.230	0, 4	0, 2
Risk of blockage detected	0.305	0.765	0, 4	0, 0
Other problem detected	0.482	1.011	0, 4	0, 0
Time freed (minutes)	5.045	10.100	– 20, 60	0, 8

IQR interquartile ranges

Table 3 Results of the linear regression explaining time freed (in min)

Variable, minutes per nurse shift	Coefficient	SE	<i>p</i> value
Intercept	− 1.375	1.677	0.414
Routine visit avoided	2.453	0.776	0.002**
End of infusion detected	2.309	0.983	0.020*
Other problem detected	− 0.693	0.395	0.082

p* value < 0.05*p* value < 0.01

that combined the visits avoided in normal and isolation rooms and separated the event of early enough detection of end of infusion from the other events. Regression coefficients are presented in Table 3. These results imply, for example, that using the Monidor solution initially requires an average of 1.375 min additional time per nurse shift, but a single routine visit avoided using the Monidor solution already provides an average freed time of 2.453 min, thus more than recovering the initial extra time requirement. The predictors of “visits avoided” and “end of infusion detected” were found to be statistically significant ($p < 0.050$) and included in the health economic model through time freed.

Table 7 in the Supplementary Appendix shows the consecutively more elaborate models and corresponding AICs.

Table 4 shows the economic effects of the Monidor solution use per month for an example department with 3 morning, 3 evening, and 2 night shifts. In this example, using the Monidor solution freed monthly capacity amounting to at least €1270.90, which was mainly due to nurse time freed (22.170 h valued at €629.64) and reduced material use when routine visits to isolation rooms were avoided (€491.93). In summary, the material savings related to the Monidor solution amounted to around half of the freed monthly capacity. This freed capacity more than offset the costs of the Monidor solution (€350.00), giving a positive return of investment of 2.63.

Table 4 Economic results of the Monidor solution for the hypothetical example department, per month

Quantity per month	Amount	Unit value (€)	Value (€)
Routine visits avoided			
Normal rooms	414.527	n.v.*	–
Isolation rooms	108.835	4.52 (materials)*	491.93
End of infusion detected	326.056	n.v.*	–
Unusual speed detected	333.446	n.v.	–
Risk of blockage detected	74.666	2.00 (materials)	149.33
Other problem detected	128.081	n.v.*	–
Time freed (hours)	22.170	28.40/h	629.64
Subtotal (€)			1270.90
Monidrop devices	10.000	35.00/device	350.00
Total (€)			920.90
Net ROI			2.63

Some items were not valued (n.v.), although they probably have a direct economic value

*E.g., normal room routine visits avoided and end of infusion detected were included in the health economic model through the time impacts regression as they were statistically significant drivers of time freed; thus, these should include only materials or other than nurse’s time, if valued

Results of the one-way sensitivity analysis over a 1-month time horizon are shown in Fig. 2. The coefficients in the regression explaining time freed were identified as the largest drivers of uncertainty. The intercept and the coefficient for visits avoided had the largest impacts on net ROI, with results ranging from 1.55 to 3.71 (compared to the base-case ROI of 2.63). In the sensitivity analysis scenario, where the potential capacity freed due to early enough detection of risk of blockage are based on

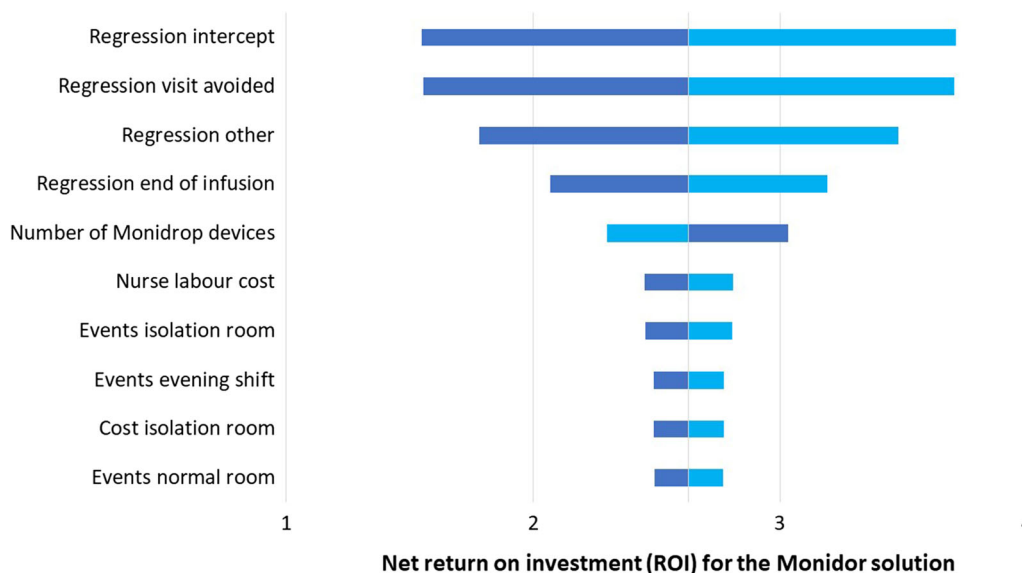


Fig. 2 Net return on investment (ROI) for the Monidor solution in the one-way sensitivity analyses

hospital price lists for the IV cannula insertion, the value of capacity freed with Monidor solution was estimated at €4,895.49 and the net ROI increased to 12.99. Consequently, positive net ROI was demonstrated consistently across all sensitivity analyses.

DISCUSSION

We evaluated the economic aspects of the Monidor solution used for the management and remote monitoring of gravity-based IV infusions in Finland. The health economic evaluation was based on explorative surveys and decision analytical modelling.

The questionnaire study demonstrated that most (56.3%) nurses experienced time freed, and only < 3.5% experienced additional time requirements with the Monidor solution. Per nurse shift, the Monidor solution helped to avoid on average 2.064 routine room visits, detect end of infusion 1.340 times, and freed 5.045 min of work time. Thus, the survey confirmed that management and remote monitoring of IV infusion administration using the Monidor solution frees nurse time. These survey study and health economic modelling results are supported by multiple case studies [26–33].

With a typical shift duration of 7.500 h, this amounts to more than 1.1% of nurse time, i.e. a considerable reduction, even though we used conservative median imputation for the respondents who estimated that the use of the Monidor solution impacts time, but who were unable to provide a numerical estimate of the amount of time. Imputation with mean values would have resulted in more time freed as the distribution was skewed to the right.

Using linear regression analysis, we identified that the time freed was statistically significantly driven by avoided routine visits to patient rooms (2.453 min per visit avoided) and earlier detection of end of infusion (2.309 min per event). In a hypothetical example department, we estimated that the value of the capacity (materials representing 49.5% and labour costs the rest) freed for other purposes is at least €1270.90 per month, which more than offsets the Monidor solution investment costs, with an estimated net ROI of 2.63. With the sensible inclusion of anaesthesiologist time freed with the early enough detection of risk of blockage, the net ROI increased to 12.99. The net ROI of the Monidor solution was robustly positive in the sensitivity analyses.

When extrapolating the survey results (on average 2.267 IV infusions per nurse shift), the

main results presented in Table 4 correspond to 552 IV infusions in 1 month. If the annual number of IV infusions carried out in Finland is about 5 million (among the population of approximately 5.5 million Finns in 2021), that is, about 416,667 IV infusions per month, then the results in Table 4 represent approximately 1.3 % of the Finnish total, and the potential capacity freed through a wider adoption of the Monidor solution is immense: assuming Finnish transferability as such, the potential capacity freed with the Monidor solution in Finland could be approximately €1 million per month). In addition, especially the working time freed by the Monidor solution may help improve patient and nurse satisfaction at the workplace, reduce stress, and thereby potentially contribute to addressing needs for improved effectiveness and the current workforce shortage in the healthcare sector.

Study strengths include being the first economic study of remote IV infusion monitoring in a real-world setting, based on a broad sample of Finnish hospitals, and a relatively large sample size for this type of study. To facilitate the application of unit costs, extrapolation to 1 month, and interpretation of the results, we have also developed an online user-interface model, which allows easy adaptation of model inputs to a specific hospital department (link available on request). As the inputs used for valuing health care resources were set conservatively and not all effects were valued, the results of the study are unlikely to exaggerate the economic benefits of the Monidor solution.

The main study weaknesses relate to practical aspects of the data collection. Because data were collected after the introduction of the Monidor solution in hospital wards, there was no obvious comparator for which data could be collected simultaneously. The comparison made here is based entirely on the subjective experiences reported by the nurses using the remote IV monitoring solution. Potential biases due to this counterfactual setup could not be evaluated. Additionally, there was considerable heterogeneity across the surveyed departments in terms of numbers of routine room visits

avoided and numbers of end of infusion detected early enough to avoid cannula occlusion, but no evidence of heterogeneity in terms of reported time freed per nurse shift. This variation is quite natural, given the recent Australian real-world evidence [24], where the proportion of females or the use of IV antibiotics significantly increased the risk for phlebitis, infiltration or occlusion and failure, while older age significantly decreased the risk of phlebitis and failure. Vascular access team's catheters were significantly less likely to dislodge, and all-cause failure was significantly increased by wrist or hand, antecubital fossa peripheral IV, and 22- or 24-gauge catheters [24]. We weighted the respondents inversely proportional to the number of respondents in the ward, such that each ward was allocated the same weight in the analysis. We would have liked to include the type of shift in the regression analysis but found this impossible given the number of responses.

The estimates of economic capacity freed presented here are likely underestimates because the only quantified impacts considered were routine visits to isolation rooms avoided, cannula change material costs, and nurse time reported. Among the additional relevant outcomes that we would have liked to include if data had been available are the impacts on patient LOS, treatment outcomes, patient well-being, and nurse satisfaction. In a case study, all respondents from two health care centres recommended the Monidor solution to their colleagues, and 87.5% reported that the IV screen had increased their work satisfaction [32]. Future research should also include more details on the clinical outcomes of IV care, such as cannula effects, including incidence of infiltration and phlebitis, and their health economic impact. Theoretically, when the Monidor solution frees time by not having nurses assess cannulas so often, the risk of cannula problems may also partly increase, particularly in at-risk populations, such as paediatric, elderly, or cognitively impaired patients.

Here, we compared the Monidor solution to common gravity-based infusions without an infusion pump or electronic controller. In

comparison to the conventional infusion pumps, remote monitoring with the Monidor solution may decrease the traffic to, and avoid beeping alarms in, patient rooms. This is an advantage that can be beneficial for nurse time and coping and patients' well-being. This should be studied in the future.

Our main goal was to study the potential effectiveness of the remote IV therapy monitoring for material- and nurse time-related capacity freed in different hospital wards. Our study excluded patient well-being and adverse effects such as patient pain for the replacement of a failed catheter, while including these would benefit the Monidor solution. The Monidor solution seems to fit well in digitalisation strategies aiming to free economic capacity. In line with earlier Finnish economic analyses of eHealth solutions (e.g. [34, 35]) and user-interface modelling [36, 37], the Monidor solution was robustly predicted to free capacity for other purposes. The Monidor solution has had high demand during the COVID-19 pandemic [29, 38], and we expect it to also work well in the future.

These survey results were based on real-world commissioning settings and nurses' responses, but they enabled estimation of effects and time-related impact based on user assessment. In the future, we plan to carry out an empirical study using objective time measurements on how Monidor effectiveness varies by type of different (gravity-based) IV infusions, such as crystalloids, antibiotics, nutrition, and blood transfusion. Further research should also investigate the implications of these effects on infection protection or management, seeing that the Monidor solution helps reduce routine room visits and may decrease patient room disturbances.

CONCLUSIONS

With the use of the Monidor solution, routine room visits including visits to isolation rooms can be avoided, and impending cases of infusion errors can be detected earlier. The economic impact and nurse time capacity freed through these effects was estimated and justifies

investment in the Monidor solution in Finnish hospital wards. These findings could be confirmed in a comparative empirical study.

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Author Contributions. Antti Puolitaival, Mikko Savola, and Erkki Soini contributed to the study conception and design. Material preparation and data collection were performed by Antti Puolitaival and Mikko Savola. Analyses were performed by Christian Asseburg, Tuomas Lundström, and Erkki Soini. A user-interface model was built by Christian Asseburg, Tuomas Lundström, and Erkki Soini on ESiOR Oy's platform. The first draft of the manuscript was written by Antti Puolitaival, Mikko Savola, and Christian Asseburg, and all authors commented on and contributed to previous versions of the manuscript. Revisions were managed by Erkki Soini. All authors read and approved the final manuscript.

Disclosures. Antti Puolitaival, Mikko Savola, and Petri Tuomainen are shareholders of Monidor Oy, and Antti Puolitaival and Mikko Savola are also employees of Monidor Oy. Erkki Soini is CEO, shareholder, and employee of ESiOR Oy, and Christian Asseburg and Tuomas Lundström are employees of ESiOR Oy. Monidor Oy is the producer and Finnish marketer of the Monidor solution. Monidor Oy commissioned ESiOR Oy

to carry out the economic analyses presented here. ESiOR Oy is not involved in the production of the Monidor solution. ESiOR Oy carries out studies, statistical analysis, consultancy, education, reporting, health economic evaluations, and market access services for pharmaceutical, food industry, diagnostics and device companies, hospitals, consultancies, academic institutions, and projects, including producers and marketers of IV infusions. The authors have no other conflicts of interest to declare.

Compliance with Ethics Guidelines. We complied with the relevant ethical guidelines and the study was performed in accordance with the Helsinki Declaration of 1964 and its later amendments. Ethical approval was not required based on the Finnish legislation because the study and data collection were non-interventional and non-medical. Nurses were incentivised to participate in the questionnaire study, but participation was totally voluntary and based on consent. Patients were not involved.

Data Availability. The datasets generated and analysed during the current study are not available because consent for data sharing was not obtained.

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