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Interruptions during intravenous medication administration: a multicenter observational study

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ABSTRACT

Aims: To determine the frequency and cause of interruptions during intravenous medication administration, which factors are associated with interruptions and to what extent interruptions influence protocol compliance.
Background: Hospital nurses are frequently interrupted during medication administration, which contributes to the occurrence of administration errors. Errors with intravenous medication are especially worrisome, given their immediate therapeutic effects. However, knowledge about the extent and type of interruptions during intravenous medication administration is limited.
Design: Multicenter observational study.
Methods: Data were collected during two national evaluation studies (2011/2012 and 2015/2016). Nurses were directly observed during intravenous medication administration. An interruption was defined as a situation where a break during the

administration was needed or where a nurse was distracted but could process without a break. Interruptions were categorized according to source and cause. Multilevel logistic regression analyses were conducted to assess the associations between explanatory variables and interruptions or complete protocol compliance.
Results: In total, 2526 intravenous medication administration processes were observed. During 291 (12%) observations, nurses were interrupted 321 times. Most interruptions were externally initiated by other nurses (19%) or patients (19%). Less interruptions occurred during the evening (Odds Ratio: 0.23, (95%-Confidence Interval: 0.08-0.62). Do-not-disturb vests were worn by 61 (2%) nurses. No significant association was found between being interrupted and complete protocol compliance.
Conclusion: An interruption occurred in every eight observed intravenous medication administration, mainly caused by other nurses or patients. One needs to critically consider which strategies effectively improve safety during the high-risk nursing-task of intravenous medication administration.

SUMMARY STATEMENT

Why is this research needed?

- Although interruptions have frequently been studied, little is known about interruptions during the administration of intravenous medication.
- Administration errors with intravenous medication have a higher risk for patient harm in comparison to errors with non-intravenous medication.
- Determining the frequency and cause of interruptions in a multicenter setting and over an extended period of time can help to create a broader overview of the extent of interruptions.

What are the key findings?

- Nurses were interrupted during one out of every eight intravenous medication administrations.
- Do-not-disturb vests were implemented in most hospitals, but rarely worn during intravenous medication administration.

How should the findings be used to influence policy/practice/research/education?

- The current practice focuses on preventing the interruptions, while based on our results, it seems that such approach is not sufficient.
- Dealing with interruptions / resilience training could be of added value in the high- risk nursing task such as the administration of intravenous medication.

INTRODUCTION

Interruptions during health care delivery are common in the daily work of nurses in hospitals, with an average of seven (range 1-42) interruptions per hour (Biron, Loiselle, & Lavoie- Tremblay, 2009; Dante et al., 2016). An interruption can be defined as ‘a temporary break of a human activity (initial task), with the assumption that this initial task will be resumed’(Brixey et al., 2007). Interruptions can be initiated by the nurse him/herself (internal), or by other individuals or objects such as pump alarms (external). Although interruptions can positively influence nurse performance and patient care (e.g. a nurse is interrupted to hear information about the health status of the patient), most interruptions are considered as breaks with negative outcomes, such as loss of focus or delays in tasks (McGillis Hall et al., 2010).

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Background

Of all nursing tasks, medication administration is the one most interrupted (Dante et al., 2016). Approximately 10-66% of the nurses are being interrupted during medication administration (Hayes, Jackson, Davidson, & Power, 2015; Moss, Berner, Bothe, & Rymarchuk, 2008; Trbovich, Prakash, Stewart, Trip, & Savage, 2010). The large difference in interruption frequencies between studies may be explained by differences in setting, used definitions and type of medication observed. Being interrupted has been identified as a contributing factor for a lower medication administration protocol compliance (Schilp, Boot, de Blok, Spreeuwenberg, & Wagner, 2014; Westbrook, Woods, Rob, Dunsmuir, & Day, 2010). Lower protocol compliance has been associated with medication administration errors (MAEs) and patient harm (Hayes et al., 2015; Keers, Williams, Cooke, & Ashcroft, 2013). In particular intravenous (IV) medication administration is considered a high-risk task, given the immediate therapeutic effects of IV medication (Institute for Safe Medication Practices (ISMP), 2015). Therefore, acquiring knowledge about the extent and type of interruptions during IV medication administration is of great importance. This knowledge can be helpful in designing interventions aimed at minimizing or preventing interruptions and medication errors related to them.
To our knowledge, only two observational studies focused on interruptions during the administration of IV medication, both conducted in North-America (United States and Canada), in single centers (Moss et al., 2008; Trbovich et al., 2010). One specifically investigated the administration of IV chemotherapy and not IV medication in general (Trbovich et al., 2010).

THE STUDY

Aims

This study aimed to determine: (1) the frequency and cause of interruptions during IV medication administration in hospitals; (2) which factors are associated with interruptions during IV medication administration; and (3) to what extent interruptions influence compliance with the prevailing protocol for safe injectable medication administration.

Design and Setting

We conducted a prospective observational multicenter study with a focus on interruptions during IV medication administration. The data used for this study were collected during two national evaluation studies conducted in 2011/2012 and 2015/2016. In both studies, compliance with the protocol for safe injectable medication (which contains intravenous medication) administration was evaluated (Schilp et al., 2014; Schutijser et al., 2018). This protocol contains 25 proceedings for administering injectable medication and is based on the ‘five rights’ of safe medication administration (right patient, right medication, right dose, right route, right time)(Hughes & Blegen, 2008). In total, 22 hospitals participated in the study (three university hospitals, eight tertiary teaching hospitals and 11 general hospitals). Thirteen hospitals participated in both studies, along with another six (2011/2012) and three (2015/2016) hospitals that participated in only one evaluation. The 19 hospitals in the first study were randomly selected to participate and originated from a stratified sample based on area and type of hospital. Of these 19 hospitals, 13 agreed to participate in the second study. The main reasons for non-participation in the second evaluation were time constraints due to the implementation of a new hospital Electronic Health Record system and a recently conducted comparable evaluation by own hospital staff. For the second study, three additional hospitals were selected from a new stratified random sample. The STROBE guideline was used for reporting this study (von Elm et al., 2008).

Participants

Nurses working on intensive care units (ICU), internal medicine wards and general surgery wards were directly observed during the administration of IV medication. All nurses (and trainee nurses) involved in the administration of IV medication on the these wards were eligible to participate.

Ethical considerations

As this study did not fall within the scope of the Dutch Medical Research (Human Subjects) Act, the medical ethical committee waived the requirement of informed consent (protocol numbers: 2011/359 and 2015/430). Nevertheless, verbal consent from nurses and (wherever possible) patients was obtained prior to observations. Nurse managers from the participating wards were informed about the purpose of the study. Nurses were aware that they were being observed and were informed about the purpose of the observations: administration of IV medication. Nurse participation in the study was voluntary and anonymous.

Data collection

During weekdays between 6AM and 10PM, nurses on the study wards were directly observed while administering IV medication to patients >18 years of age. It involved observing all IV medications, except parenteral nutrition, chemotherapy and acute medications. At each hospital, trained external researchers conducted the observations during consecutive weekdays. During each observation, the following items were registered: (1) whether or not the administrator was interrupted during the administration; (2) whether or not the administrator was wearing a do-not-disturb vest; and (3) describing the interruption in detail (free text). It was possible to be interrupted more than once during one administration.

Sample size

The sample size calculations in both evaluation studies were based on protocol compliance as outcome measure. In the first evaluation study, data were collected per hospital once a month but at 10 different moments to monitor process variation over time and calculate an average compliance rate. To detect a 10% improvement, at a 5% significance level (ß=0.8), at least 300 observations were needed in the second evaluation study. Therefore, one data collection moment per hospital was sufficient. Although this sample size was not based on interruption related outcomes, a sample of 300 observations among at least 100 nurses was considered as high (Biron et al., 2009).

Primary outcomes

The primary outcomes were the frequency and causes of interruptions during IV medication administration. In this study, a broad definition for an interruption was used (Box 2): a situation where a nurse needed to temporarily break the IV medication administration or a situation where a nurse was distracted but could ignore or process without a break in the IV medication administration (Biron et al., 2009; Brixey et al., 2007). Both situations were recognized as having negative influence on the safety of the medication administration procedure.

For the analyses of causes of interruptions, each interruption was categorized as internally or externally initiated (e.g. initiated by the nurse him/herself, by other individuals or objects) (Brixey et al., 2007). Furthermore, a distinction was made between interruptions with a break and interruptions without a break (i.e. distractions). Questions from other HCP, patients and family were considered as interruptions with a break when nurses responded to these questions. Finally, causes of interruptions were categorized into human, technical or environmental (Biron et al., 2009). Human interruptions are caused by HCP, patients, family, either directly or by means of telephone calls, since the caller initiated the call (Biron et al., 2009). Technical interruptions are caused by alarms (e.g. pagers, infusion pumps) or operational failures (e.g. collecting additional attributes necessary to administer the medication).

Environmental interruptions are caused by contextual circumstances during the administration such as noise, light, smell and crowdedness.

Secondary outcomes

Secondary outcomes were factors associated with interruptions and the influence of interruptions on protocol compliance. To determine factors associated with interruptions, four explanatory variables were registered per observation: study period (2011/2012, 2015/2016),

type of ward (general surgery, internal medicine, intensive care), moment of administration (morning, afternoon, evening) and wearing a do-not-disturb vest (yes/no). Study period was chosen as a factor because the protocol could have been implemented more thoroughly in daily practice between 2011/2012 and 2015/2016 and awareness about interruptions could have been increased. Furthermore, previous studies showed that type of ward, moment of administration and wearing a do-not-disturb vest were associated with interruptions (Hall et al., 2010; Palese, Sartor, Costaperaria, & Bresadola, 2009; Verweij, Smeulers, Maaskant, & Vermeulen, 2014). To determine if protocol compliance is influenced by interruptions, protocol compliance for each IV medication administration was observed and calculated.
Prior to the first evaluation study, an expert team selected the nine most critical and identifiable proceedings from the Dutch protocol on safe injectable medication administration. These nine proceedings relate to the 'five rights' of safe medication administration and include: check medication order, prepare for administration, collect materials, identify the patient, conduct hand hygiene, check infusion line, check infusion pump mode, conduct double check by a second nurse and sign the medication order. A standardized observation form was used to observe whether or not these nine proceedings were conducted correctly by the nurses. Compliance was considered complete when all nine proceedings were correctly conducted. Each administration was scored (0-9) and then dichotomized into complete and incomplete compliance ($\leq$8 proceedings correctly conducted) (Schilp et al., 2014).

Validity and Reliability

The external researchers, who conducted the observations and were not employed in the hospitals, used a similar observation list during both research periods. The researchers were either nurses or research assistants with a biomedical Master's degree. During both
observation periods researchers were trained in performing observations during one day and follow-up trainings were conducted to discuss definitions and common observation situations (Schilp et al., 2014). During the observations, nurses were unaware that interruptions were registered, to minimize the Hawthorne effect. However, nurses could know that interruptions were being observed, since preventing interruptions is highlighted in the current protocol which is publicly available. Furthermore, two researchers independently and retrospectively categorized the causes of interruptions. Inconsistencies were discussed with two senior researchers.

Data analysis

Descriptive statistics were used to summarize characteristics on observation level. Since the total number of interruptions was small in both evaluation studies, combined results are presented.
To assess the association between explanatory variables and interruptions, an univariate multilevel logistic regression analysis was performed. A three-level structure was used, with observations clustered in wards and wards in hospitals. One dependent variable was used: being interrupted at least once (yes/no). The four explanatory factors (study period, ward, moment, wearing a vest) were added as independent variables. Study period was centered in such a way that both study periods were equally weighted (-0.5/0.5). Intra class correlations (ICC) indicated if the relative contribution of

the hospital and ward levels differed. During the ICC calculation, all explanatory variables were taken into account.
To determine to what extent interruptions influenced protocol compliance, another multilevel analysis was conducted. In this model, the dependent variable was complete protocol compliance (yes/no) and being interrupted (yes/no) was added as an independent variable. The explanatory variables were also taken into account in this model.
Only in the descriptive analysis of causes, the distinction between an interruption with a break and an interruption without a break (i.e. distraction) was made to gain a more detailed insight.
Descriptive analyses were conducted using SPSS Statistics 20 (IBM Corporation) and the multilevel analyses using MlwiN V.2.30 (University of Bristol). The multilevel association models were calculated using Penalized Quasi Likelihood second order with constrained level 1 variance. For all analyses, p-values ≤ 0.05 were considered statistically significant.

RESULTS

In total, 2526 IV medication administration procedures were observed, of which 2154 during the first evaluation study (2011/2012) and 372 during the second evaluation study (2015/2016). Since not all hospitals participated in both evaluation studies, the total number of observations in the hospitals ranged between 22 and 196 (median=119). Most observations were conducted at general hospitals (52%), on general surgery wards (35%) and during the afternoon (59%) (Table 1). Do-not-disturb vests were worn by 61 (2%) nurses.

Frequency of interruptions

A total of 321 interruptions were identified (Table 1). These interruptions occurred during 291 observations of which 263 observations (90%) with one, 26 (9%) observations with two and two (1%) observations with three interruptions. Interruptions occurred most frequently in the morning (34%) and afternoon (65%). In 13 (4%) observations with an interruption, the nurse wore a do-not-disturb vest.

Causes of interruptions

Of 189 (59%) of all 321 interruptions, the cause of the interruption could be obtained from the observations forms. Most the interruptions were externally initiated (n=181, 96%). Of these 181 externally initiated interruptions, 135 resulted in a break and 46 in no break (i.e. distractions) (Figure 1). External interruptions with a break were mainly caused by other nurses (n=35, 19%) and patients (n=35, 19%). Whereas, distractions were mainly caused by other HCP (n=12, 6%) e.g. food delivery services to patients or by environmental situations (n=10, 5%) (e.g. noise, crowdedness). Of eight (4%) internally initiated interruptions, six resulted in a break and were caused by operational failures (i.e. a nurse putting on gloves halfway through the administration procedure instead of at the start) and one resulted in a break and was caused by a patients' family (i.e. a nurse commenced a conversation while administering medication). The remaining internally initiated interruption that resulted in a distraction was caused by the environment (i.e. administration of medication by a nurse in a busy hallway where the patient was at that moment). In Box 1, examples of other causes are described.

Factors associated with interruptions

In the first univariate analysis between independent explanatory variables and being interrupted at least once, the variable 'period' appeared not significantly associated. Therefore, a second multilevel analysis was conducted without this explanatory variable where a positive association between time of administration and being interrupted was found (Table 2). The number of interruptions decreased

significantly during IV administration in the evening compared with the morning (Odds Ratio (OR): 0.23 (95% Confidence Interval (CI): 0.08-0.62)). Other exploratory variables were not significantly associated with the occurrence of interruptions. In total, 20% (ICC=19.7) of the variance in the association between explanatory variables and being interrupted was caused by differences between individual hospitals and 2% (ICC=2.4) by differences between individual wards. This finding is supported by the number of observations with interruptions between individual hospitals: 0- 37 (median=12).

Interruptions and protocol compliance

The protocol for safe injectable medication administration was conducted completely in 14% of the observations with an interruption (Table 1), compared with 22% of the observations without an interruption. After adjusting for explanatory variables, the multilevel analysis showed no significant influence of being interrupted on the complete protocol compliance (OR: 0.85 (95% CI: 0.57-1.26)). In total, 21% (ICC=21.4) of the variance in the association between explanatory variables and complete protocol compliance was caused by differences between individual hospitals and 13% (ICC=12.5) by differences between individual wards.

DISCUSSION

During 12% of the IV medication administration observations in 22 Dutch hospitals, at least one interruption occurred, which was usually initiated by a colleague nurse or patients.
Significantly less interruptions occurred during medication administration during evening shifts. No significant association was found between being interrupted and complete protocol compliance. Differences in interruption frequency were larger between individual hospitals than between individual wards.
An interruption frequency of 12% identified in this study is at the lower end of the interruption frequency range identified in other studies: 10-66% (Hayes et al., 2015; Moss et al., 2008; Trbovich et al., 2010). The large difference in interruption frequency between the studies may be explained by differences in setting, used definitions and type of medication observed. In our study, only IV medication administrations were observed; nurses may be more aware of the risks associated with IV medication administration and therefore try to avoid interruptions during this high-risk task as much as possible. The outliers in the range,
e.g. 10% (Trbovich et al., 2010) and 66% (Moss et al., 2008), are both studies which focused on IV medication administration alone. In the first study (Trbovich et al., 2010), only IV chemotherapy administrations were observed, which protocols are even more strict compared with regular IV medication administrations. In the second study (Moss et al., 2008), both the administration and preparation of IV medication were observed on ICUs. Preparing medication in often busy medication rooms as well as the fact that the ICU setting is more prone to frequent care interventions may both explain high interruption frequency identified in the study of Moss et al. (2008).
Human actions (e.g. nurses, patients, family, other HCP) were the major cause of interruptions in our study (85%), which is line with previous studies (Bravo, Cochran, & Barrett, 2016; Westbrook et al., 2017). Due to a reduced number of nurses and HCP on wards after 6 pm, this may also explain why less interruptions occurred during evening shifts. Since humans are the major cause of interruptions, it seems logical that do-not-disturb vests, as a tool to reduce interruptions, were introduced in various hospitals (Palese, Ferro, Pascolo, Dante, & Vecchiato, 2015; Verweij et al., 2014; Westbrook et al., 2017), including the Netherlands. Although not mandatory in Dutch hospitals, most hospitals participating in this
study stated in their protocols that such vests were implemented. A do-not-disturb vest as an intervention to prevent interruptions stems from the belief that interruptions are negative situations

and, therefore, need to be avoided. We found that do-not-disturb vests were rarely worn by nurses during IV medication administration. Previous studies showed that nurse- related arguments for not wearing the vests include: disliking the color, disbelieving vests will prevent interruptions, thinking vests are unhygienic and hot and thinking the administration will take more time (Verweij et al., 2014; Westbrook et al., 2017). Since the choice of not wearing a vest seems to be based on nurses personal ideas instead of patient safety-related arguments, increasing nurses awareness regarding the consequences for patient safety could improve their acceptance of the vests. Designing a new vest, meeting nurses' needs and specifications, can also be another potential solution to addressing the low acceptance of the vests.

At the same time, nurses need to be visible (Bravo et al., 2016), need to consult people when delivering health care (Trbovich et al., 2010) and are key-informants for family and other HCP (Dante et al., 2016). These aspects of nursing make nurses more prone to interruptions, forcing them to multitask (Hayes et al., 2015; Westbrook et al., 2017). Nurses spend 15% of their shift on multitasking (Bellandi et al., 2018). Westbrook et al. (2017) found that during medication administration, 88% of the nurses conducted at least one other task (Westbrook et al., 2017). In this context, a do-not-disturb vest seems not a good fit.

Another potentially effective approach are bundled interventions, which consist of a combination of do-not-disturb vests, hourly medication rounds, posters in medication rooms, patient and family education, information material, no interruption zones and triage of phone calls (Dall'Oglio et al., 2017; Relihan, O'Brien, O'Hara, & Silke, 2010; Westbrook et al., 2017). These interventions effectively reduced the frequency of interruptions during medication administration but were not focused specifically on IV medication and did not

include dealing with multitasking or setting priorities. Therefore, our recommendation is to implement and determine the effectiveness of combined interventions aiming to reduce interruptions and simultaneously equipping nurses in dealing with interruptions, prioritizing and multitasking.

Limitations

This is the first multicenter study where interruptions during IV medication administration was determined over a four-year period. As more than 20% of all Dutch hospitals participated in this study, this strengthens its generalizability in the Dutch hospital setting. Another strength of this study is that nurses were not aware that interruptions were being measured, giving a realistic reflection of daily practice. Also, to ensure a consistent categorization of the identified interruptions, a two-step process was followed where two researchers independently analyzed causes of interruptions and in case of disagreement two senior researchers were consulted to solve it. This study also has several limitations. Data on interruptions from the first evaluation study were retrospectively analyzed. Although we were able to retrieve a majority of causes for the interruptions by analyzing the information registered by the observers, 41% of the causes could not be identified. However, compared with other studies, the magnitude and type of identified causes were similar. Therefore, we are confident that our sample represents current nursing practice. Another limitation was that it was not possible to correct for the observer effect (i.e. whether one observer registered more interruptions than another observer). In both evaluation studies, most hospitals were visited by only one observer. To correct for the observer effect, at least two observers should have conducted an equal number of observations in all hospitals and each observer should have visited several hospitals. Due to practical reasons this was not included in our study design. Finally, we did not measure the consequences of interruptions in terms of MAEs and harm resulting from MAEs or estimated whether or not an interruptions was avoidable. As an alternative, we evaluated consequences of interruptions on protocol compliance. As mentioned before, low protocol compliance is associated with MAEs and patient harm. In addition, the evaluation of avoidability of interruptions is hampered by a lack of consensus on this topic (Biron et al., 2009; Buchini & Quattrin, 2012; Dante et al., 2016).

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CONCLUSION

To conclude, in this multicenter observational study interruptions during IV medication administration occurred in one out of every eight administrations. Colleague nurses and patients are the most frequent cause of these interruptions. As do-not-disturb vests are seldom worn, one needs to critically consider what type of strategies are necessary to effectively improve safety in the process of administering IV medication by nurses. The available literature provides insufficient evidence addressing the subject of multitasking or setting priorities (Hayes et al., 2015; Westbrook et al., 2017). Future research should focus on implementing interventions which aims to reduce interruptions, along with equipping nurses in dealing with interruptions, prioritizing and multitasking.

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Conflict of Interest statement
No conflict of interest has been declared by the authors.

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Tables and figures

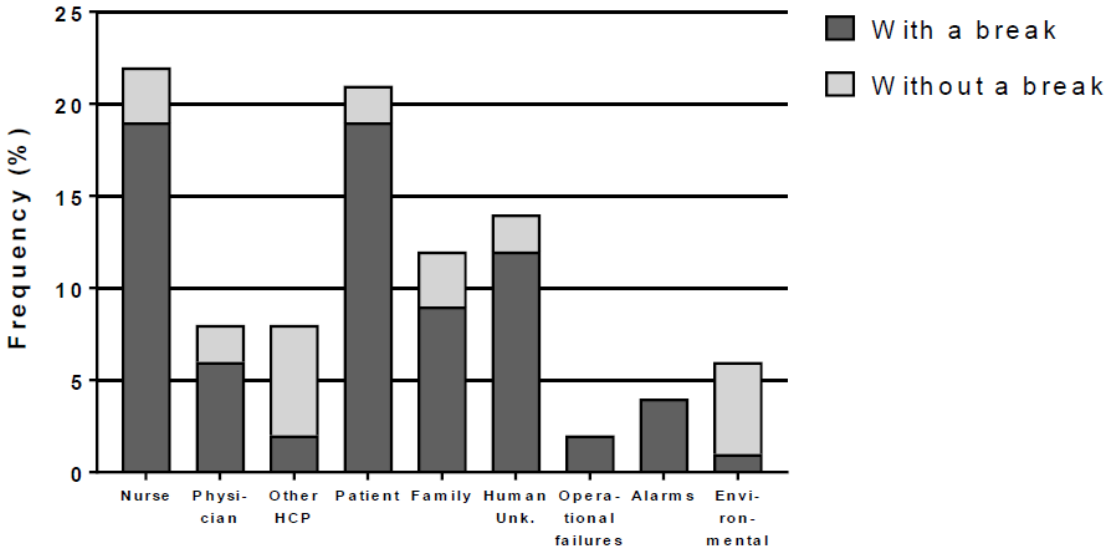
Table 1: Characteristics of the observations.

	Total number of observations N=2526	**Observations with ≥1 interruption N=291**
Type of hospital		
University	319 (13%)	41 (14%)
Tertiary teaching	889 (35%)	86 (30%)
General	1318 (52%)	164 (57%)
Type of ward		
Internal Medicine	772 (31%)	88 (30%)
(General) Surgery	883 (35%)	90 (31%)
Intensive Care	802 (32%)	103 (35%)
Other	69 (3%)	10 (3%)
Administration time		
Morning (6AM-12PM)	863 (34%)	98 (34%)
Afternoon (12PM-6PM)	1500 (59%)	188 (65%)
Evening (after 6PM)	163 (7%)	5 (2%)
Wearing a do-not-disturb vest		
Yes	61 (2%)	13 (4%)
No	2465 (98%)	278 (96%)
Complete protocol compliance		
Yes	539 (21%)	42 (14%)
No	1987 (79%)	249 (86%)

Table 2: Multilevel logistic regression analysis of the association between explanatory variables and being interrupted at least once during IV medication administration.

Explanatory variables	**Odds Ratio**	**95% Confidence Interval**
Type of hospital University Tertiary teaching General	1.09 Reference 1.56	0.26-4.53 Reference 0.68-3.61
Type of ward Internal Medicine (General) Surgery Intensive Care Other	0.99 Reference 1.22 1.40	0.65-1.51 Reference 0.81-1.85 0.52-3.75
Administration time Morning (6AM-12PM) Afternoon (12PM-6PM) Evening (after 6PM)	Reference 1.10 0.23*	Reference 0.81-1.49 0.08-0.62*
Wearing a do-not-disturb vest Yes No	1.93 Reference	0.95-3.90 Reference

* $p \leq 0.05$



Causes of external interruptions

Figure 1: Causes of external initiated interruptions divided in interruptions with a break and without a break (i.e. distractions) (n=181/189). HCP = Heath Care Professionals, Human Unk. = caused by humans, but unknown which person, Phone calls were categorized as 'Human Unknown', Environmental = noise, light, smell, or crowdedness.