Innovative approaches to improve nursing care quality

Olga Florea

NNT/NL : 0000AIXM0000/000ED000

THÈSE DE DOCTORAT

Soutenue à Aix-Marseille Université
le 25 novembre 2021 par

Olga FLOREA

Approches innovantes pour l'amélioration des soins infirmiers

Discipline

Biologie santé

Spécialité

Maladies infectieuses
Recherche clinique et Santé Publique

École doctorale

ED 62 – SCIENCES DE LA VIE ET DE LA SANTE

Laboratoire/Partenaires de recherche

Unité de recherche Microbes Evolution, Phylogénie et Infection (MEPHI), Institut Hospitalo-Universitaire

Composition du jury

Mr le professeur **Jean-Christophe LUCET**	
HOPITAL BICHAT	Rapporteur
Mr le professeur **Michel CARLES**	
CHU NICE	Rapporteur
Mme la docteure **Olivia KEÏTA-PERSE**	
CH Princesse Grace MONACO	Examinatrice
Mr le professeur **Philippe BROUQUI**	
IHU Aix-Marseille Université	Directeur de thèse
Mme la docteure **Sophia BOUDJEMA**	
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AVANT-PROPOS

Le format de présentation de cette thèse correspond à une recommandation de la spécialité Maladies Infectieuses et Microbiologie du Master des Sciences de la Vie et de la Santé qui dépend de l'Ecole Doctorale des Sciences de la Vie de Marseille.

Le candidat est amené à respecter des règles qui lui sont imposées et qui comportent un format de thèse utilisé dans le Nord de l'Europe et qui permet un meilleur rangement que les thèses traditionnelles. Par ailleurs, la partie introduction et bibliographie est remplacée par une revue publiée dans un journal scientifique afin de permettre une évaluation extérieure de la qualité de la revue et de permettre à l'étudiant de commencer le plus tôt possible une bibliographie exhaustive sur le domaine de cette thèse. Par ailleurs, la thèse est présentée sur article publié, accepté où soumis associée d'un bref commentaire donnant le sens général du travail. Cette forme de présentation a paru plus en adéquation avec les exigences de la compétition internationale et permet de se concentrer sur des travaux qui bénéficieront d'une diffusion internationale.

Professeur Didier RAOULT

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RESUME

Depuis les premières études sur l'ampleur des dommages causés aux patients, la sécurité des patients est devenue une discipline dotée d'une base théorique et des méthodes des sciences de la sécurité conçues pour mesurer les événements indésirables associés aux soins (EIAS) et apporter des améliorations concrètes et durables en vue d'empêcher la survenue d'événements similaires à l'avenir. Il ne suffit pas de reconnaître que des EIAS se produisent. Nous devons également en comprendre les causes et opérer les changements nécessaires pour prévenir d'autres dommages. Un patient sur dix décède ou est victime d'effet indésirable lors d'un soin hospitalier. Il est donc indispensable de mettre en œuvre des soins de qualité dans tous les établissements de soins. Pour améliorer la sécurité des patients, la surveillance et la prévention des infections nosocomiales sont une priorité des établissements de santé. Dans cette thèse nous avons réalisé plusieurs études utilisant des approches innovantes et multidisciplinaires avec pour objectif d'améliorer la qualité des soins et la sécurité des patients.

Afin d'avoir un panorama aussi complet que possible de la problématique nous avons pensé qu'en parallèle aux nouvelles technologies et aux approches multidisciplinaires sur la qualité des soins, le ressenti des soignants et des patients devait être investigué. C'est l'objet de notre revue systématique réalisée sur la perception des soignantes et des patients de l'utilisation des injections par cathéter sous-cutanée. Cette revue clarifie s'il y a une perception différente sur les cathéters utilisés dans les soins infirmiers. Nous avons identifié une préférence pour les cathéters par voie sous cutanée. Dans la deuxième partie, nous avons réalisé une étude transversale afin de valider un outil de relevé des soins par les soignants au lit du patient que nous avons appelé PSR pour Patient Smart Reader. L'utilisation de cet outil au lit du patient améliore considérablement la traçabilité des soins, en particulier celle des cathéters veineux périphériques. Dans la troisième partie, nous avons souhaité améliorer la traçabilité des cathéters veineux périphériques en utilisant une des techniques de

communication très rarement utilisée en santé appelée communication engageante. Cette étude a été rendue possible par la collaboration avec l'école de journalisme et de communication Aix-Marseille Université. Nous avons utilisé le système d'enregistrements des soins infirmiers au lit du patient cité plus haut combiné avec une communication engageante. Les analyses ont été faites en utilisant une carte de contrôle et une analyse de série chronologique. Cette étude a montré la pertinence de la combinaison entre la technologie et les approches de sciences humaines et sociales pour améliorer la traçabilité des cathéters veineux périphériques.

Dans la quatrième partie, une étude longitudinale a été réalisée pour explorer l'hygiène des mains dans les situations à risques de transmission croisée. En effet il n'existe pas à ce jour de système automatisé de surveillance de l'hygiène des mains qui, comme les audits de l'OMS, recueille la compliance spécifique lors des gestes à risque (moment 2 de l'OMS). Nous avons ici combiné des technologies différentes pour tenter de surveiller la désinfection des mains des soignants au cours d'un geste aseptique. Cette étude montre que lors des gestes à risque, l'hygiène des mains est insuffisamment pratiquée. Il est important à l'avenir de développer des technologies permettant de cibler l'hygiène des mains dans les situations les plus à risque de transmission.

Cette thèse montre la faisabilité d'approches nouvelles et multidisciplinaires pour améliorer la qualité des soins infirmiers. L'impact sur la transmission des microorganismes responsables d'infections liées aux soins reste à démontrer.

Mots clés : infections liées aux soins, qualité des soins, sécurité des soins, technologies innovantes, approche multidisciplinaire hygiène des mains, soins infirmières.

ABSTRACT

From the earliest studies of the extent of patient harm, patient safety has evolved into a discipline with a theoretical foundation and safety science methods designed to measure care-associated adverse events (ADEs) and provide concrete and lasting improvements to prevent similar events from occurring in the future. It is not enough to recognize that AEIS do occur. We also need to understand the causes and make the changes necessary to prevent further damage. One in ten patients dies or suffers an adverse reaction during hospital treatment. It is therefore essential to implement quality care in all health care establishments. To improve patient safety, the surveillance and prevention of nosocomial infections are a priority for healthcare establishments. In this thesis, we have carried out several studies using innovative and multidisciplinary approaches with the objective of improving the quality of care and patient safety.

In order to have as complete a panorama as possible about the problem, we thought that in parallel with new technologies and multidisciplinary approaches to the quality of care, the feelings of caregivers and patients should be investigated. This is the subject of our systematic review on the perceptions of caregivers and patients on the use of subcutaneous catheter injections. This review clarifies if there is a different perception about catheters used in nursing care. We have identified a preference for subcutaneous catheters. In the second part, we carried out a cross-sectional study in order to validate a tool for recording care by caregivers in the patient's bed that we called PSR to Patient Smart Reader. The use of this tool at bedside greatly improves the traceability of care, that of peripheral venous catheters. In the third part, we want to improve the traceability of peripheral venous catheters by using communication techniques very rarely used in health called engaging communication. This study was made possible by the collaboration with the Aix Marseille University School of Journalism and Communication. We used the above-mentioned bedside nursing recording system combined with engaging

communication. Analyzes were done using a control chart and time series analysis. This study showed the relevance of the combination of technology and social science approaches to improve the traceability of peripheral venous catheters.

In the fourth part, a longitudinal study was carried out to explore hand hygiene in situations at risk of cross-transmission. Indeed, to date, there is no automated hand hygiene monitoring system which, like the WHO audits, collects specific compliance during risky acts (WHO moment 2). Here we have combined different technologies to try to monitor the disinfection of the hands of caregivers during an aseptic procedure. This study shows that during risky actions, hand hygiene is insufficiently practiced. It will be important in the future to develop technologies to target hand hygiene in situations with the highest risk of transmission.

This thesis shows the feasibility of new and multidisciplinary approaches to improve the quality of nursing care. The impact on the transmission of microorganisms responsible for healthcare-related infections remains to be seen.

Keywords: infections linked to care, quality of care, safety of care, innovative technologies, multidisciplinary hand hygiene approach, nursing care.

ABBREVIATION

AHR	Alcohol-based hand rub
HCW	Healthcare worker
IAS	Infections associées aux soins
IHU	Institut hospitalo-universitaire
IoT	Internet des Objets
MIT	Maladies infectieuses et tropicales
MHT	MediHandTrace®
OMS	Organisation mondiale de la santé
PRISMA	Preferred reporting items for systematic reviews
PRISMA-ScR	Preferred reporting items for scoping reviews
PSR	Patient Smart Reader®
PVC	Peripheral venous catheter
SC	Subcutaneous catheter

INTRODUCTION

Sécurité du patient et qualité de soins

La sécurité des patients est une discipline dotée des méthodes des sciences de la sécurité et conçue pour mesurer les événements indésirables associés aux soins (EIAS) et apporter des améliorations concrètes et durables en vue d'empêcher la survenue d'événements similaires à l'avenir [1]. Il ne suffit pas de reconnaître que des EIAS se produisent. Nous devons comprendre les causes et appliquer les changements nécessaires pour prévenir d'autres dommages.

La qualité des soins est un objectif majeur de tout établissement de santé et la sécurité des patients est un élément essentiel de la qualité des soins. Elle consiste à éviter les risques, les erreurs et les préjudices causés aux patients [2]. Il est estimé que 134 millions d'événements indésirables se produisent chaque année en raison d'accidents médicaux dans les hôpitaux, ce qui contribue à environ 8,5 à 8,8 millions de décès [3,4].

Infections associées aux soins

Les infections associées aux soins (IAS), sont des événements indésirables majeurs dans les établissements de santé qui affectent les patients [5]. Les infections associées aux soins appelée aussi infections nosocomiales sont des infections contractées au cours d'un séjour dans un établissement de santé (hôpital, clinique…). Ces infections sont absentes au moment de l'admission du patient dans l'établissement. Cependant, si l'état infectieux du patient à l'admission est inconnu, l'infection est généralement considérée comme nosocomiale si elle apparaît après 48 heures d'hospitalisation. Elle est généralement définie comme une infection cliniquement apparente chez les patients alors qu'ils reçoivent des soins à condition que celle-ci ne soit pas en incubation au moment de l'admission. Les infections peuvent être directement liées aux soins dispensés au patient (par exemple l'infection sur cathéter) ou

simplement survenir lors de l'hospitalisation, indépendamment de tout acte médical (par exemple une épidémie de coronavirus). Les IAS sont liées en majorité à une contamination directe à partir d'un dispositif invasif cathéter, sonde urinaire et autres avec la flore endogène du patient. Il existe plusieurs types d'infections nosocomiales relevant de modes de transmission différents : - le malade s'infecte avec ses propres micro-organismes, à la faveur d'un acte invasif et/ou en raison d'une fragilité particulière ; - les micro-organismes ont pour origine les autres malades (transmission croisée entre malades ou par les mains ou matériels des personnels), les personnels ou la contamination de l'environnement hospitalier (eau, air, équipements, alimentation…). Les IAS comportent : Les infections sanguines (bactériémies) avec des portes d'entrée variées, mais pour lesquelles le cathéter est la principale porte d'entrée , les infections des voies urinaires associées à l'utilisation de cathéters, les pneumonies associées à l'utilisation de ventilateurs, et les infections du site opératoire [6]. Les IAS sont caractérisées par une résistance accrue des micro-organismes aux anti-microbiens, généralement associées à un séjour hospitalier prolongé et aboutissant à des dommages justifiant des procédures judiciaires et finalement un coût très lourd pour la société. Les IAS dans les pays développés affectent 5 à 15 % des patients hospitalisés [7]. En ce qui concerne les données de 2017 en France, les infections nosocomiales restent un problème persistant, la prévalence est de 5,8 % ; le taux de prévalence en France est supérieur à celle de l'Union e européenne [8]. La prévention et la surveillance des IAS doivent rester la priorité des établissements hospitaliers.

Hygiène des mains

En 1847, Semmelweis, a rapporté la première démonstration de l'association entre la transmission de la fièvre puerpérale et le lavage des mains [9]. L'hygiène des mains, que ce soit

par le lavage ou la désinfection des mains, reste la mesure la plus importante pour prévenir les infections nosocomiales [10,11]. Il a été rapporté que les mains contaminées du personnel soignant ont été à l'origine d'IAS endémiques ainsi que de plusieurs foyers épidémiques

d'IAS [12,13]. Une étude montre que plus de 70 % des IAS sont liées à une hygiène des mains insuffisante [14]. L'hygiène des mains est l'une des méthodes les plus efficaces pour lutter contre les IAS [15]. L'organisation mondiale de la santé (OMS) a identifié cinq moments pendant les soins où l'hygiène des mains devrait toujours être appliquée : 1) avant tout contact avec un patient, 2) avant toute intervention aseptique, 3) après une exposition aux liquides biologiques, 4) après tout contact avec un patient 5) après avoir été en contact avec l'environnement du patient [16]. Il apparaît que le risque de transmission croisée entre le soignant et le patient n'est probablement pas du même ordre lors du Moment 2 que lors du Moment 5. Toutefois, dans la pratique quotidienne les recommandations ont été simplifiées par la désinfection avant de rentrer dans la chambre et en en sortant. La compliance à l'hygiène des mains par le personnel soignant reste très faible, avec des taux de compliance observés allants de 30 à 50 %, ce qui est inférieur au niveau minimum de 91 % recommandé par l'OMS [15,17]. Une étude a montré qu'une réduction de 6 % des IAS est associée à l'augmentation de 10 % de la compliance à l'hygiène des mains [18].

L'OMS recommande l'observation directe pour évaluer la compliance à l'hygiène des mains. Toutefois, l'observation directe risque d'avoir un biais nommé « l'effet Hawthorne ». La présence de l'auditeur peut influencer la personne auditée et induire ainsi un biais [19]. Pour diminuer l'effet et prévenir la transmission croisée, des technologies innovantes de surveillance automatisées ont été développées qui permettent de mesurer l'hygiène des mains de façon automatique, continue dans le temps avec une traçabilité minutieuse.

Approches innovantes dans le domaine de la prévention et de la prise en charge des IAS

La technologie joue un rôle important dans la pratique clinique et dans la gestion des hôpitaux, comme les dossiers patients informatisés combinés à des codes-barres, les systèmes de surveillance automatique, les aides au diagnostic par intelligence artificielle, les systèmes

de surveillance à distance des patients [20,21]. Elle réduit les tâches non nécessaires tout en permettant d'obtenir des données plus précises. La mise en place de processus automatiques de gestion de données contribuera vraisemblablement à l'amélioration future des soins de santé.

Nous avons fait le choix d'une approche multidisciplinaire intégrant les sciences humaines et sociales, la microbiologie, l'épidémiologie, le contrôle des infections, et l'utilisation de technologiques innovantes développées et validées cliniquement, pour lutter contre ces problèmes actuels de santé publique.

Les résultats de cette approche constituent le corps principal de cette thèse.

PARTIE I : Revue systématique : perception des cathéters sous-cutanées par les soignants et les patients

Préambule

Du fait du nombre croissant des maladies nosocomiales lié à l'utilisation des voies d'administration des médicaments, les approches innovantes sont essentielles pour les voies d'administration. L'utilisation des nouveaux protocoles dans la prise en charge des patients nécessite de revoir l'état actuel d'administration des médicaments parmi les voies les plus utilisées, comme la voie veineuse périphérique et la voie sous-cutanée. La quantité importante d'effets indésirables de l'administration des médicaments par voie veineuse périphérique, nous suggère de choisir une voie d'administration moins dangereuse, mais avec une pharmacocinétique similaire, comme c'est le cas de la voie sous-cutanée. Nous avons rédigé une revue systématique (Article N°1) pour répondre à une question de recherche : Quel est la perception des patients et des infirmières pour l'administration des médicaments par voie sous-cutanée ?

Cette revue a appliqué la méthodologie d'Arksey et O'Malley et la liste de contrôle PRISMA extension for scoping reviews (PRISMA-ScR). Nous avons recherché tous les articles scientifiques publiés, en mettant l'accent sur les dernières technologies et les développements innovants dans le domaine des soins de santé et du contrôle des infections. Nous avons inclus tous les types de schémas d'étude et de contextes cibles. Toutes les bases de données électroniques ont été scannées jusqu'en 2021. Cinq bases de données ont été consultées systématiquement (PubMed, Web of Science, Dimensions, Cochrane Library et Summon). Après avoir supprimé les doublons, 486 citations ont été récupérées, enfin 16 articles sont identifiés éligibles pour cette revue.

Nous avons identifié dans les études la présentation de la perception des patients et la perception des soignants. Cette revue de cadrage permet de dresser une cartographie des tendances de la perception et la préférence des patients et des soignants en matière de soins infirmiers. Nos

résultats indiquent que la tendance la plus prometteuse est l'utilisation de la voie sous-cutanée en raison des résultats positifs, lesquels ont été validés dans la plupart des études analysées.

Article N°1: Perceptions of Subcutaneous Administration by Nurse and Patient: A Scoping Review

FLOREA O, BROUQUI P and BOUDJEMA S

Soumis dans Nursing Open

REVIEW ARTICLE

Perceptions by the nurse and the patient of subcutaneous administration of fluids ore medications? A scoping review

Olga Florea[1,2] RN, MS**, Philippe Brouqui**[1,2] MD, PhD, **Sophia Boudjema**[1] RN, PhD

[1] Aix Marseille University, IHU-Méditerranée Infection, MEPHI, Marseille, France

[2] AP-HM, IHU-Méditerranée Infection, Marseille, France

Corresponding author: Brouqui P: philippe.brouqui@univ-amu.fr

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ABSTRACT

Aim

Although poorly documented, subcutaneous (SC) administration of fluids or medication represents a major alternative when other parenteral routes of administration cannot be used. We aim to clarify key concepts and knowledge gaps when it comes to patient and nursing perception of SC administration.

Methods

This scoping review followed the methodology of scoping review guidance from Arksey and O'Malley. Five databases were searched systematically (PubMed, Web of Science, Summon, Dimensions and Cochrane Library) published in the English language from 2011 to 2021, identifying the patient and nurse perception of subcutaneous administration as an alternate route for fluids or medication. After the removal of duplicates, 486 citations were retrieved and 16 were included in the analysis using the PRISMA extension for scoping reviews.

Conclusions

Our findings indicate that the most preferred administration, according to patients and nurses, is the subcutaneous route over intravenous. Subcutaneous infusion improves the quality of nursing care. It is well perceived by the patient and by the nurse

Keywords: subcutaneous administration, venous administration, nursing perception, nursing preference, patient perception, patient preference

1. BACKGROUND

At present, the parenteral administration of medication is frequent, mainly due to the poor oral absorption of many commercialized formulations and when the oral route cannot be used. Intravenous (IV) administration is an invasive procedure that exposes the patient to the risk of infectious and thrombotic complication(s) [1,2]. Peripheral venous catheters are indeed associated with blood stream infection (BSI) and septic venous thrombosis with an incidence of 0.18%[3]. When the placement of a central venous catheter or an implantable chamber is required, the rate of catheter related BSIs goes up to 2.7 per 1000 catheter-days [4] and the mortality within 30 days of the BSI was 13.9% in a cohort of non-ICU patients [5]. In a similar population, PICC-line associated bacteremia was reported with a prevalence of 2.27% and an overall 30-day mortality of 22.09 % [6].Venous catheters are the major causes of bacteremia. Considering that 56% of peripheral venous catheters inserted at the hospital admission are unnecessary , the priorities are to monitor the use of these unnecessary catheters, [1] and to promote alternatives including the subcutaneous (SC) route of administration [2]. SC route of administration is largely used in geriatric and palliative care patients, mostly when venous access is difficult (due to poor venous access) or difficult to maintain (cognitive and behavioral disorders), or to facilitate hospital discharge [7]. In these populations, the intramuscular (IM) route of administration may also be difficult to use, especially for long-term therapies, because of the frequent co-administration of anticoagulant drugs [8]. In a randomized trial comparing the SC and IV route for rehydration in geriatric patients, the SC route was found to be far superior when IV puncture was difficult to achieve, particularly when used on confused patients [9].

A rising number of studies describe the use of the SC route versus the IV route. A better understanding of the efficacy and safety of SC administration of medications is fundamental to reduce the number of IV lines and their associated complications. Although many factors can influence the absorption of subcutaneous administration, such as low blood flow at the injection

site, fat and muscle mass, total body water and albuminemia, recent studies described acceptable pharmacokinetic and pharmacodynamic data for SC administration of medications [10,11].

A lot of reviews of the literature concluded that SC is the patients' preferred route of delivery [12–18]. Using the SC route, has the potential to improve the satisfaction of patients and the safety of health care. We reviewed the literature on SC administration, with an emphasis on nursing and patient perception for SC administration.

This scoping review aims to identify knowledge on subcutaneous route administration. The research question is centered on the perception of subcutaneous administration by nurse and patient.

2. METHODS

This review followed the methodology of scoping review guidance from Arksey and O'Malley and the PRISMA extension for scoping reviews (PRISMA-ScR) checklist [19,20]. The protocol of our review does not need to be registered. For methodological quality (risk of bias) assessment, no formal methodological quality assessment of the included articles was conducted under guidelines for conducting a scoping review [19,21,22].

2.1. Eligibility criteria

We searched all the scientific papers published, centered on the subcutaneous and venous administration route and the perception of them by patient and nurse. All electronic databases were screened in August 2021.

The time frame for publication was limited to the last 10 years (2011 -2021), which we considered a reasonable period to define the up-to-date investigation. Articles are limited by being written in English, peer-reviewed journals, and the availability of full-text contents.

Articles were excluded if the studies were reviews, case reports, and if the study was about autoinjection SC administration.

2.2. Information sources

A comprehensive literature search was conducted in the following electronic databases from 2011–2021: PubMed, Web of Science, Dimensions, Cochrane Library and Summon (Aix-Marseille university network). The key search terms were based on subcutaneous and intravenous administration, nurse and patient perception.

2.3. Search strategy

The following search terms were used: Subcutaneous, intravenous, perception, preference, patient, nursing.

2.4. Data charting process and data items

All the search results were imported into Zotero 5.0.96.2. for Windows, and all the data (e.g., title, authors, date, and abstracts) were exported into an Excel file for screening. A data charting form was determined after the discussion of results.

We extracted article description, including the author names, date of publication, study design, country, target setting, nursing activity, administration route used, patient perception, nurse perception, sample size, study period and outcome.

2.5. Synthesis of results

For each study, we identified nursing category and type of perception for subcutaneous administration of medication. To focus on the perception in nursing category, we counted the number of studies by perception category for each nursing category. To determine the impact of SC or IV injection on the perception of patients and nurse, we analyzed each article and defined four categories of outcome: efficiency, effectiveness, performance and quality [23].

Therefore, we counted the numbers of studies by each perception category and each outcome category.

3. RESULTS

3.1. Overview of the search results

In total, 777 citations were identified from searching in electronic databases and 27 through hand-searching. After the removal of duplicates, 486 articles were retrieved for the title and abstract screening, and 286 articles were excluded, with 200 full-text articles to be assessed for eligibility. Of these, 184 articles were excluded due to the following: 99 were off topic, 43 contained SC auto-injection , 9 were commentary articles, 8 had irretrievable full-text content and another 25 were removed because of review content. Finally, 16 articles remained eligible for this review and included different countries (**Figure 1**). The studies were heterogenous, conducted mostly on patients hospitalized in geriatric, palliative care, or infectious diseases wards, but some studies included ambulatory patients.

The characteristics of the included articles are summarized in **Table 1**. Among the 16 articles included in the analysis, 1 was a quasi-experimental study, 3 were validation studies, 3 were observational studies, 6 were descriptive studies, and 3 were randomized controlled trials.

This review grouped the perception in 3 sections: 1) patient perception that is presented in 8 articles; 2) nurse perception that is included in 5 articles; and 3) patient and nurse perception in 3 articles.

This review analyzed all the activities related to nursing, grouped into four major categories: (1) infection prevention and control (IPC) as an essential element of patient safety and the quality of care; for this reason, the consequence impacts not only patients but also healthcare workers. 5 articles were identified in this category; (2) nursing management: 3 articles were identified in this category; it is an important part of nursing to improve nursing

quality and patient satisfaction. It includes all processes, including planning or organizing, such as decision support/making, patient management and care management; (3) nursing education: including healthcare workers continuous training and school training for students, 2 articles were identified in this category; (4) nursing assessment: it is the first step and fundamental in the nursing process and daily care, such as the pain of patients: 6 articles were in this category. Some articles were identified in each of those categories, also including comparison versus intravenous administration.

3.2. Synthesis of results

The types of injection route used in nursing are represented in **Figure 2**.

Most of the studies focused on patient perception (50%). IPC and nursing assessment categories were equally focused on patient perception. **Table 2**. Moreover, 31,25 % of studies addressed the perception of the nurses while 18,75 % of studies were focusses on joint patient and nurse perception, with these two sets of articles being equal in IPC, nursing assessment and nursing education. The types of perception involved in nursing care was illustrated in **Figure 3**.

All articles were analyzed for the outcome category, and this review defined four aspects of outcome. We considered efficiency as minimizing unnecessary time and efforts of nursing (doing the right thing), effectiveness as optimizing the clinical practice of nursing (doing things right), performance as optimizing the process of nursing, and quality as minimizing the

healthcare system errors from daily care to provide patient safety [23]. **Table 3** shows the number of studies reporting above defined outcomes on nursing perceived by patient and or nurses: 43.75% of studies (N = 7) analyzed effectiveness, 18.75% of studies (N = 3) analyzed performance, 18.75% of studies (N = 3) analyzed quality, and 18.75% of studies (N = 3) analyzed efficiency. **Figure 4** illustrated the outcome on nursing care for SC and IV infusion.

SC infusion is well perceived in the four categories of nursing outcome, while IV infusion has a worse perception on care quality than SC infusion.

The SC injection facilitated nursing quality of care as demonstrated by a high acceptance rate for use and a low complication rate in the inpatient hospital setting. According to the results, all 100 (100%) of the nurses who used the SC injection reported that the device was easy to use and 98 (98%) reported that they would like to use it again in the future to care for patients requiring multiple subcutaneous injections. Additionally, 97 (95.1%) reported no complications with the device (**Table 4**). These is different for IV injection as reported in **Table 5** . The nurses perception of SC versus IV infusion is illustrated in **Figure 5**.

The SC infusion improved patient ‘s satisfaction by reducing patient anxiety and needle’s pain during the hospital stay. According to the results, 39 (39%) of the patients identified that they had needle anxiety before insertion. Upon insertion and use of the SC injection, all 39 (100%) identified decreased anxiety. Additionally, 98 (98%) of the patients identified that the SC was comfortable to wear and made it easier to receive subcutaneous medications than the traditional method of multiple skin injections **Table 6.**

The IV infusion do not decrease patient ‘s needle anxiety and pain, and is coupled with discomfort experienced when the patient would wear clothing on top of the IV (**Table 7**). The patient’s perception of SC versus IV infusion is illustrated in **Figure 6**.

The SC injection proved to be efficacious in our evaluation by providing a safe route for subcutaneous injections, reducing needle anxiety, and increasing both patient and nurse satisfaction.

3.3 Prevention of complications

The most frequent adverse events associated with the use of SC route are mild local complications (oedema, erythema, pain). More severe local complications have been described,

such as cases of cutaneous necrosis associated with SC perfusion [24,25], but it remains a rare complication with only 5 cases reported for a total of more than 10,000 SC injections in this review. For comparison, peripheral venous catheter which equipped approximately 63% of patients admitted to European hospitals are causing thrombophlebitis, lymphangitis and infection in 0.2-0.7/1000 days [4]. To achieve better tolerability, it is recommended to rotate the perfusion sites every 72 to 96h [26], and to use non-rigid catheters from 20 to 27G [27]. The use of metallic needles or rigid catheters has been shown to significantly increase the number of local AEs. The antibiotics can be diluted either in 0,9% saline solution or in glucose solution, although the use of glucose solution is more frequently associated with mild local AEs [7]. A rapid infusion is associated with the occurrence of local AEs [28], and a prolonged infusion over 30 minutes could help improve tolerability.

4. DISCUSSION

Among the 16 papers reviewed, our findings indicate that the SC injection is most preferred by the patient and by the nurse versus IV injection.

4.1 Preference and perception

Results revealed that respondents who preferred SC compared with IV administration reported motivations that were more related to convenience, mainly due to reduction in the duration, more time efficient for the institution and avoiding the discomfort of administration [29–31].

Patients who preferred intravenous infusion emphasized their feeling of safety provided by the presence of qualified personnel who administer the therapy [31].

Patients appreciated the convenience that characterizes subcutaneous injections, but also emphasized the importance of feeling safe during the administration. The study suggests that the choice of prescribing subcutaneous injections or intravenous infusions should be discussing possible resistances and avoiding preconceptions about patients' preferences, and these options

being shared with patients. Subcutaneous administration is associated with higher utility values compared to intravenous administration [32].

Switching from IV to SC was successful, proving that SC offers a good alternative to IV. The SC route maintain drug efficacy and it the effect on disease but showed improved satisfaction and quality of life.[33,34] The relative costs of intravenous and subcutaneous administration are highlighted and the results of a patient survey indicates a strong preference for subcutaneous administration [35].

Most nurse providers preferred SC over IV administration. Patient preference, time saved and convenience contributed to the positive experience with SC administration [36]. Also, healthcare professional preference confirmed that SC is preferred with no safety impact [37].

The few negative comments made demonstrated a need for proper staff training in SC administration. The possibility of home administration in the future also seemed acceptable [38].

Patient and physician characteristics influence the choice of SC versus IV therapy. These findings suggest to shared decision-making, which could improve treatment satisfaction, adherence and improved patient outcomes[39].

In the concept of cancer management, the advent of subcutaneous injection represents important progress, that is based also on patient preferences [40,41].

Also, the varying of the injection speed has no influence on the pain experienced during subcutaneous injection[42]. However, higher injection volumes caused more pain. To use the appropriate injection site and technique to reduce their injection pain is necessary. These findings may have great implications for the development of drug formulations and new injection devices for clinical practice [43].

The results of this study acknowledge the hospital practice of subcutaneous administration of medication as a feasible, nonburdensome, and safe method. Nevertheless, the SC administration is not free from complications, needs appropriate nursing care, and requires standardized procedures [44]. Often, factors influencing the use of subcutaneous route to hydration were linked to the context and professionals' subjective perceptions about this medical practice, the characteristics of the patient, and their family [45].

The pain is a side effect associated with the subcutaneous administration of drugs that should be considered, as it may negatively impact on the quality of life of patients. The subcutaneous administration of drugs can impact positively on patients' perception by improving the formulations [46].

4.2. Strengths and limitations

This review was conducted using a rigorous procedure and followed the standards of the methodology throughout the whole process to screen pertinent articles and achieve research questions (Arksey & O'Malley, 2005; Levac et al., 2010; Tricco et al., 2018). Although this review aimed to use research terms as wide as conceivable to retrieve all relevant articles, while restricting articles related to centrals catheters or other administration routes, we might have missed some articles. To form a reasonable scope, the considered time frame was constrained to 10 years. This limitation might miss some meaningful studies; however, in the field of administration routes of medications, we consider this period a rational restriction.

In general, studies with negative results are usually not published; thus, publication bias should be considered here. To avoid misunderstanding due to the translation, our search strategy was only focused on articles published in English, which could be a limitation of this review. However, translation software tools have been developed with great progress in recent years, and most studies are published in English.

One challenge in this review is the grouping of administration medications categories. In some studies, several routes could be used simultaneously. However, this review identified the main route, which is more dominant in each study, a strategy that should be considered a limitation. However, two authors identified study characteristics and categories independently and checked the agreement after discussion to limit bias. Finally, due to the scoping review design of the study, an assessment of bias regarding the limitations of methodology or risk is usually not performed (Munn et al., 2018).

5. CONCLUSIONS

This scoping review provides a map of the evidence of patient preference and nurse preference.

Results suggest that the subcutaneous (SC) route is the patient-preferred method of drug delivery when compared with intravenous (IV) administration. Patient preference ought to be addressed in future randomized controlled trials examining drug efficacy and safety if different modes of administration are available. Patient preference for route of drug administration has implications for adherence and quality of life, so it is important in treatment decision making.

The subcutaneous infusion provides an opportunity to increase the quality of nursing care using a safe and effective device that minimizes the amount of skin injections for patients, requiring routine subcutaneous injections, while improving patient satisfaction by reducing discomfort and anxiety. It demonstrates an improvement in patient/nurse satisfaction and nursing perceived quality of care through its ease of use. Subcutaneous access should be considered alongside intravenous therapy for hydration in older adults. There are additional benefits in terms of ease of use and cost-effectiveness of this mode. Inclusion of subcutaneous access in clinical guidelines may promote uptake of this route to help preserve vessel health of vulnerable patients. Further high-quality research is needed to inform subcutaneous infusion therapy in a

variety of populations (including pediatrics and palliative care) and medications and clarifying the mechanism of delivery.

CONFLICT OF INTEREST

Authors declare no conflicts of interest.

AUTHOR CONTRIBUTION

All authors have agreed on the final version and meet at least one of the following criteria [recommended by the ICMJE (https://www.icmje.org/recommendations/)]: substantial contributions to conception and design, acquisition of data or analysis and interpretation of data; drafting the article or revising it critically for important intellectual content.

ETHICAL APPROVAL

As this was a scoping review, Research Ethics Committee approval was not required in this study.

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DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study are included in this published article (and its supplementary information files).

Figure 1 PRISMA flow chart for scoping review

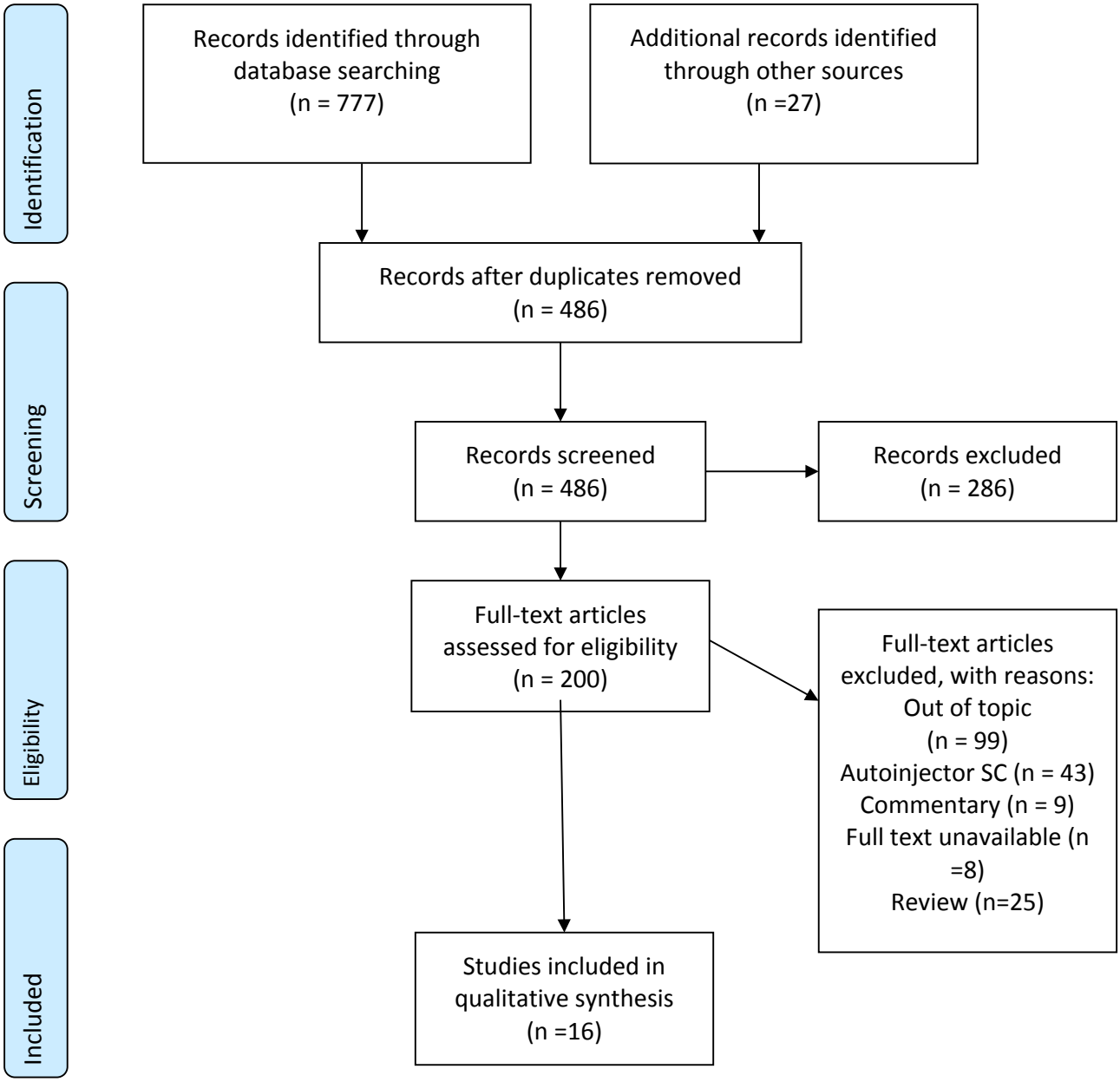


TABLE 1 Characteristics of included articles

Characteristics	Categories	*N*	(%)
Study Design	Quasi-experimental	1	6
	Validation study	3	19
	Observational	3	19
	Descriptive	6	37
	Randomized control trial	3	19
Perception	Patient	8	50
	Nurse	5	31
	Patient and nurse	3	19
Nursing	Infection Prevention and Control	5	31
	Nursing management	3	19
	Nursing education	2	13
	Nursing assessment	6	37

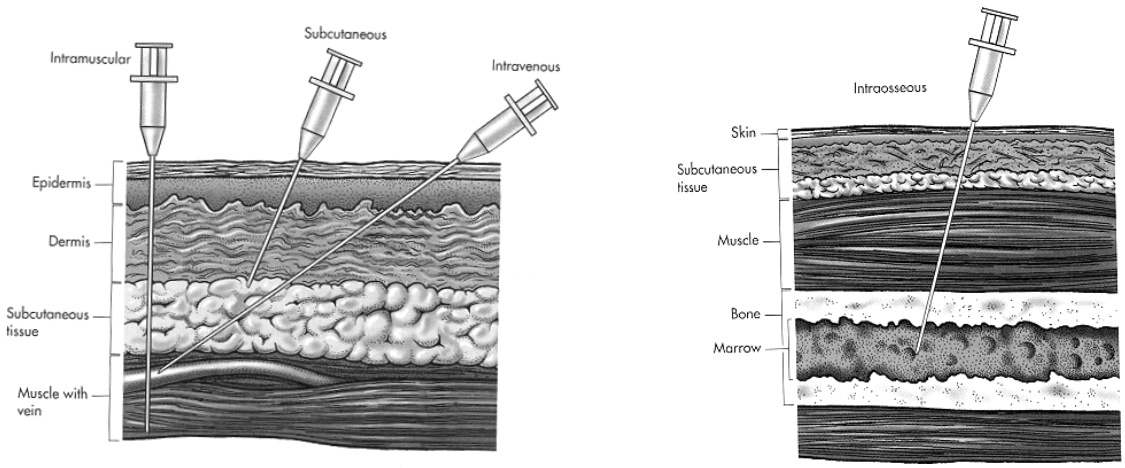


Figure 2: Intramuscular, subcutaneous, intravenous routes and Intraosseous routes

TABLE 2 Number of studies by perception category and nursing activities

Perception	Nursing activity				
	Infection prevention and control	Nursing assessment	Nursing education	Nursing management	Grand Total
Patient	3	3	0	2	8
Nurse	1	2	1	1	5
Patient and nurse	1	1	1	0	3
Grand Total	5	6	2	3	16

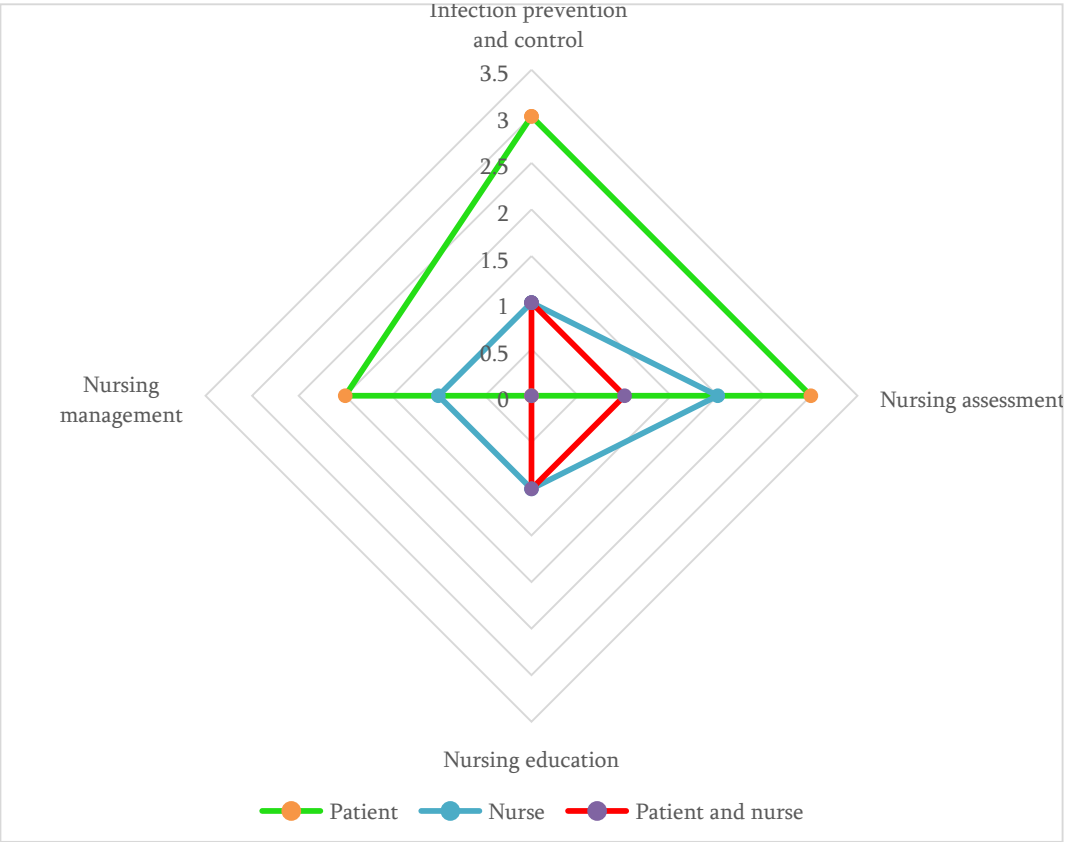


FIGURE 3 The types of perception involved in nursing care. This chart presents the numbers of reviews of each section of perception in each nursing category.

TA B L E 3 Impact of perception on nursing. Numbers of studies by each perception section and each outcome category

	Impact category				
Perception	**Effectiveness**	**Efficiency**	**Performance**	**Quality**	**Grand Total**
Patient	4	2	1	1	8
Nurse	2	1	1	1	5
Patient and nurse	1	0	1	1	3
Grand Total	7	3	3	3	16

F I G U R E 4 The types of injection outcome in nursing care. This chart presents the percentage of nurses' perception for subcutaneous injection and intravenous injection in each outcome category.

TABLE 4 Nursing evaluation tool for subcutaneous injections

N 100	YES	NO	N/A
Easy to use	100 (100%)	0 (0%)	0 (0%)
Like to use the product with future patients	98 (98%)	1 (1%)	1 (1%)
Safe for patient use	98 (98%)	0 (0%)	2 (2%)
Observed complications	2 (2%)	98 (98%)	0 (0%)

TABLE 5 Nursing evaluation tool for intravenous injections

N 100	YES	NO	N/A
Easy to use	38 (38%)	52 (52%)	10 (10%)
Like to use the product with future patients	38 (38%)	41 (41%)	21 (21%)
Safe for patient use	36 (36%)	62 (62%)	2 (2%)
Observed complications	82 (82%)	18 (18%)	0 (0%)

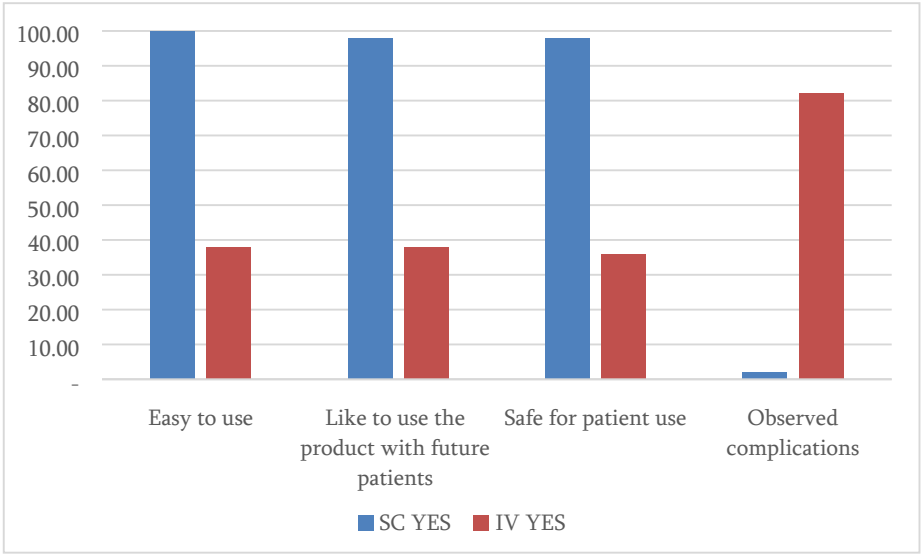


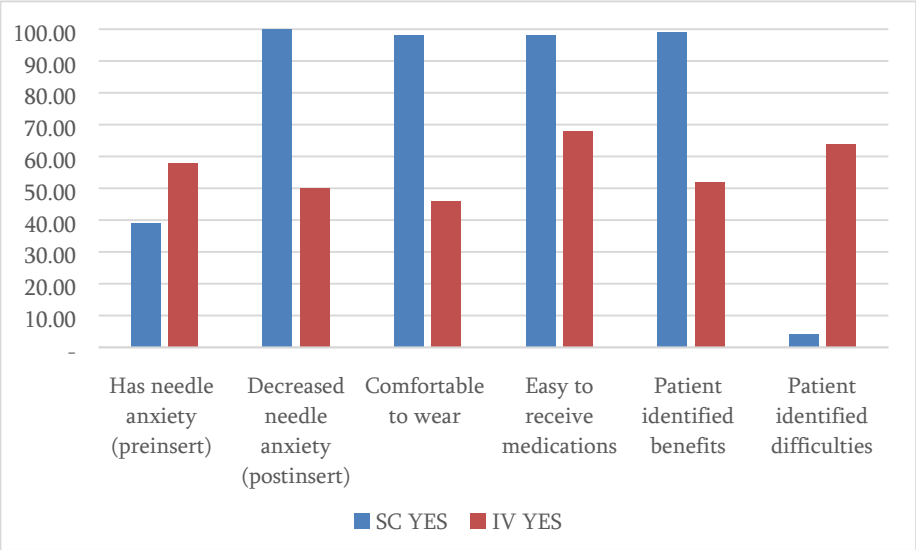
FIGURE 5 The nursing perception involved in nursing care. This chart presents the percentage of nursing perception for subcutaneous injections and intravenous injection in each evaluation tool

TABLE 6 Patient satisfaction Sheets for subcutaneous injection

N 100	YES	NO	N/A
Has needle anxiety (preinsert)	39 (39%)	61 (61%)	0 (0%)
Decreased needle anxiety (postinsert)	39 (100%)	0 (0%)	61 (100%)
Comfortable to wear	98 (98%)	1 (1%)	1 (1%)
Easy to receive medications	98 (98%)	1 (1%)	1 (1%)
Patient identified benefits	99 (99%)	0 (0%)	1 (1%)
Patient identified difficulties	4 (4%)	95 (95%)	1 (1%)

TABLE 7 Patient satisfaction Sheets for intravenous injection

N 100	YES	NO	N/A
Has needle anxiety (preinsert)	58 (58%)	42 (42%)	0 (0%)
Decreased needle anxiety (postinsert)	29 (50%)	29 (50%)	42 (100%)
Comfortable to wear	46 (46%)	53 (53%)	1 (1%)
Easy to receive medications	68 (68%)	21 (21%)	11 (11%)
Patient identified benefits	52 (52%)	36 (36%)	12 (12%)
Patient identified difficulties	64 (64%)	35 (35%)	1 (1%)



F I G U R E 6 The patient perception involved in nursing care. This chart presents the percentage of patient perception for subcutaneous injections and intravenous injection in each satisfaction sheet.

Supplementary material:

Subcutaneous infusions (hypodermoclysis)

They are especially useful in palliative care, in hospices and for the elderly, especially in the patient's home (performed by trained caregivers). They are cheaper and safer than IV infusions. Subcutaneous punctures, unlike intravenous punctures, do not cause thrombosis, and they also cause less discomfort to the patient.

Indications

1. Hydration of slightly or moderately dehydrated patients, especially in the elderly and in children. It is the method of choice in the terminal stage of illness (if hydration does not lengthen the suffering and the death process).

2. Continuous infusions or regular and frequent injections of 2-4 ml of drug solutions, in patients with difficulty receiving oral medications, especially in patients with nausea and vomiting after radio or chemotherapy, in the elderly and in terminally ill.

Contraindications

1. General: overhydration, thrombocytopenia and other coagulation disorders, absolute indications for intravenous administration of drugs (need to administer> 3 L / 24 h of fluids or parenteral nutrition, life-threatening acute conditions).

2. Local: subcutaneous tissue too thin, puncture site difficult to access, injection causes discomfort, absorption is limited by a tumor or ulceration, poor local skin condition (inflammatory condition, lymphatic edema, local damage, eg. eg after radiotherapy).

Complications

Redness, pain, blood in the cannula or "butterfly" needle drain, bleeding, obstruction of the cannula → change the puncture site. Local accumulation of fluid is not harmful.

Team

1. Metallic “butterfly” needle: traditionally used, equipped with a drain that facilitates the administration of medications. Contraindications in nickel allergies.

2. Synthetic cannula: as in cases of peripheral vein catheterization, more often Ø 0.4-0.6 mm (26-23 G).

3. Injection pump: preferably a special one for subcutaneous drug administration.

4. Liquids to be administered subcutaneously

1) type: the solution of choice is 0.9% NaCl; 0.45% NaCl, 5% glucose, polyelectrolyte solution, Ringer's lactate, mixture of NaCl with glucose (eg 1/3 5% glucose + 2/3 NaCl 0) can also be administered, 9%); 20-40 mEq of KCl can be added to 1000 ml of the liquid administered in slow infusion

2) volume: up to 3 l / 24 h (more comfortable with 2 simultaneous punctures); a max amount can be administered. 500 ml for 1 hour, 6 × d.

5. Drugs: those most used subcutaneously in palliative care (they can be joined in the same syringe) are: hyoscine butyl bromide, haloperidol, levomepromazine, metoclopramide, midazolam, morphine, tramadol. The dose is calculated from the oral dose. 0.9% NaCl (isotonic, does not cause irritation) or water for injection, sometimes 5% glucose is used as diluent.

6. The rest of the equipment as in the case of subcutaneous puncture.

Puncture site.

A place with sufficient thickness of subcutaneous tissue. Most often: upper rib cage below clavicle, outer thigh, above or below scapula, outer shoulder, abdominal wall.

Technique

1. Introduction of the "butterfly" needle:

1) Obtain the patient's permission, wash and disinfect hands, put on gloves, prepare and disinfect the skin as in subcutaneous injection

2) Remove the “butterfly” from the packaging without removing the needle cap

3) Fill the "butterfly" drain (with 0.9% NaCl, water for injection, other liquid to administer or drug mixture)

4) Remove the needle cap

5) Lift the skin fold by grasping it with the thumb and index finger

6) Insert the “butterfly” needle into the subcutaneous tissue at an angle of 45 ° (in the rib cage parallel to the ribs)

7) Evaluate the correctness in the placement of the needle (in case of blood leakage change the puncture site)

8) Make a "butterfly" drain hoop (prevents needle mobility, tissue irritation and accidental needle removal)

9) Fix the "butterfly" with a dressing

10) Make another ring with the drain and if necessary, decrease its length

11) Document the procedure (as in peripheral venous catheter insertion.

2. Introduction of the synthetic cannula: as with the “butterfly” needle, but omit points 2, 3, 8 and 10. Withdraw the needle after inserting the cannula under the skin.

3. Infusion rate (1 ml of the liquid = 20 drops): specify the number of drops per minute and calculate the infusion time according to the formula:

number of drops = infusion volume (ml) × 20 drops min expected infusion duration time (h) × 60

With flows of 75 ml / h (1500 drops / h = 25 drops / min), local accumulation of fluid is generally not achieved.

After the procedure

If no complications have occurred, the “butterfly” needle or cannula may remain in the subcutaneous tissue for up to 10 days.

Drugs can be administered by many routes. The goal is to deliver the drug to the target organ or tissue so it can exert its therapeutic effect. EMS personnel can deliver drugs by several routes. An understanding of possible methods to deliver a drug is required as part of using the drug for therapeutic benefit.

Routes for administration of drugs and time until effect

Route for administration	Time until effect
intravenous	30-60 seconds
intraosseous	30-60 seconds
endotracheal	2-3 minutes
inhalation	2-3 minutes
sublingual	3-5 minutes
intramuscular	10-20 minutes
subcutaneous	15-30 minutes
rectal	5-30 minutes
ingestion	30-90 minutes
transdermal (topical)	variable (minutes to hours)

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PARTIE II : Amélioration de la Traçabilité des Soins par Personal Digital Assistant

Préambule

Cette deuxième partie est consacrée à un dispositif permettant de relever les soins au lit du patient et donc d'éviter les retranscriptions sur papier. L'objectif principal était d'améliorer la traçabilité des soins (quantitative et qualitative) et tout particulièrement la surveillance des cathéters, la dématérialisation au lit du patient pouvant permettre de réduire la transmission croisée. La traçabilité des soins est obligatoire, et elle est réalisée en général loin de lieux de soins qui donnent la place à l'oubli ou manquement qui a poussé au développement d'outils spécifiques (**Annexes 1-2**). Ce système de traçabilité au lit du patient appelé Patient Smart Reader® a été développé en collaboration avec un bureau d'études spécialisées dans la traçabilité (MicroBE Toulon Var) sur la base de matériel PDA médical commercialisé sur lequel a été développé un logiciel spécifiquement pour ces objectifs. Une étude transversale (**Article N°2**) a été effectuée pour valider son utilisation.

Nous avons évalué la conformité à la traçabilité des soins infirmiers au chevet du patient à l'aide du Patient Smart Reader®, un assistant numérique personnel avec un code-barres.

Nous avons comparé différentes façons de tracer les soins comme l'enregistrement papier (dossier de soins infirmiers), des logiciels informatiques spécifiques du système d'information hospitalier et le Patient Smart Reader®.

Le Patient Smart Reader a amélioré l'enregistrement de 90 % des soins infirmiers par rapport aux autres moyens traditionnels. Concernant l'insertion de cathéters sanguins, les taux de conformité sont passés de 44,19 % à 100 %, et la surveillance des cathéters sanguins est passée de 29,64 % à 80,74 %. La surveillance du cathéter urinaire et l'enregistrement de l'insertion ont augmenté de 10,23 % à 55,43 % et de 16,67 % à 100 %, respectivement.

Fournir aux soignants des outils de relever des soins au lit du patient en temps réel a considérablement amélioré la traçabilité des soins infirmiers.

Article N°2: Improving Health Care Workers' Compliance with Traceability by Recording the Nursing Process at the Point of Care Using a Personal Digital Assistant with a Barcode

Olga FLOREA, Jean Charles DUFOUR, Chloe MAGNIN, Philippe BROUQUI and Sophia BOUDJEMA

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Improving Health Care Workers' Compliance with Traceability by Recording the Nursing Process at the Point of Care Using a Personal Digital Assistant with a Barcode

Olga Florea[1,2], Jean Charles Dufour[3], Chloe Magnin[1,3], Philippe Brouqui[1,2] and Sophia Boudjema[1,2]*

[1]Aix Marseille Université, IRD, MEPHI, IHU-Méditerranée Infection, Marseille, France
[2]AP-HM, IHU-Méditerranée Infection, Marseille, France
[3]Aix Marseille Université, AP-HM, INSERM, IRD, SESSTIM, Hop Timone, BioSTIC, Marseille, France

Abstract

Background: Adverse events are serious, and frequent complications are most often linked to the quality of nursing care.

Purpose: We evaluated the compliance to traceability of bedside nursing care using the Patient Smart Reader®, a personal digital assistant with a barcode.

Methods: We compared paper record forms, specific computer software in the hospital information system and the Patient Smart Reader®.

Results: The Patient Smart Reader enhanced the recording of 90% of the nursing care surveyed. Regarding the insertion of blood catheters, compliance rates increased from 44.19% to 100%, and blood catheter monitoring increased from 29.64% to 80.74%. Urinary catheter monitoring and insertion recording increased from 10.23% to 55.43% and from 16.67% to 100%, respectively.

Conclusion: Providing caregivers with a nursing record system that uses barcodes at the point of care in real time significantly improved the traceability of nursing care.

Keywords: Electronic records • Nursing records • Personal digital assistant • Adverse event • Hospital-acquired infection • Blood catheter • Urinary catheter • Traceability

Introduction

An adverse event (AE) is any unexpected event that follows any act or action performed or prescribed by a health professional. Adverse events are widespread and have a significant cost; it was estimated that the total costs of preventable AEs in the USA were between $17.1 billion and $29 billion annually [1]. The two most frequent classes of AEs, postoperative infections and pressure ulcers, accounted for the highest annual costs (6.5 billion USD) [2]. The prevalence of AEs can vary from 7 to 40%, but it is important to note that AEs can be avoided in more than half of the cases and that 27.6% of AEs are related to negligence and 76.8% to inappropriate nursing care [2,3]. In intensive care units (ICUs), AEs are associated with more extended hospital stays [4]. In Canadian hospitals, a study reported that 20.8% of deaths are related to AEs, and the authors estimated that the death rate due to AEs in Canada as a whole is > 38,000 annually [5]. The expected goal in caring for patients is to provide low mortality, low morbidity, and a low readmission ratio after 30 days, with a better quality of life. The Institute of Medicine suggests that improving data collection and analysis of direct patient care would enhance patient safety [6]. According to the "knowing how to prevent" adage, traceability of care is likely to be a significant component of the surveillance and prevention of AEs, suggesting that better traceability should lower the frequency of AEs and their consequences. The use of the 'Check List' in anesthesia has demonstrated a significant reduction in mortality [7]. It has been suggested that as many as 70% of adverse events could be avoided if the right information about the right patient is available at the right time, and health information exchange makes this possible. In agreement with the recommendations of most national authorities, the care provided by healthcare workers (HCWs) is currently registered in the patient's hospital electronic health record (EHR). The quality of nursing care is related to the execution of the nursing process, which should be adequately documented [8]. Currently, transferring from paper-based documentation to electronic documentation is commonly available worldwide. Whether computerized or not, the patient's health information is most often recorded manually and outside of the location of the nursing care (the patient's room), resulting in forgetfulness and inaccuracy. While many studies throughout the world have evaluated the impact of EHRs on the quality of nursing care, few studies have specifically evaluated the pertinence of a bedside care recorder for the quality of traceability. A comparison of personal digital assistant (PDA) records at the bedside with paper formats suggest that PDAs used at the bedside are reliable, allow for fewer errors, are easy to use, and are advocated by interviewers [9,10]. To improve the quality of nursing care records, the nursing care act should be recorded in real time, meaning that a bedside solution is needed. Some studies have reported nursing record evaluations at the point of care [11,12], but quantitative analyses of compliance with the traceability of nursing care records have not yet been reported in prospective comparative case-control protocols.

The researchers of this study developed a personal digital assistant with a barcode, named the Patient's Smart Reader® (PSR), to trace nursing care at the patient's bedside in real time. The aim of this study is to evaluate the impact of such a tool on the compliance of HCWs with recording nursing care in the care unit by successively comparing different nursing care recording tools. The hypothesis was that recording nursing care at the patient's bedside in real time would improve compliance with the traceability of nursing care.

***Address for Correspondence:** Sophia Boudjema, IHU Mediterranee Infection, 19-21 BD Jean Moulin, 13005, Marseille, France, Tel: 33621523355, E-mail: sophia.boudjema@univ-amu.fr*

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Materials and Methods

This study was conducted in the infectious and tropical diseases medical unit of the university hospital in Marseille, France, which consisted of 17 beds. For the purpose of our research, we decided to divide the unit into two distinct parts, namely, nine beds (for cohort A) and eight beds (for cohort B). All voluntary HCWs (doctors, nurses, nursing assistants, and housekeeping personnel) of the unit were included in the study.

Recorder systems

When a HCW provides nursing care to a patient, he/she must track the care in the nursing care record. The validity of this information must be certified with the time and date of the nursing care and with the signature of the HCW. We compared different traceability systems that were used in patient medical records. The oldest traceability system was a dedicated paper form. This sheet of paper was placed into the patient's paper-based medical record. The second traceability system, the software Pharma® (version 5.8.70602.1 300), was introduced in our institute in 2013 and allows the traceability of medical prescriptions and administered drugs but also provides some of the patient's parameters, such as urine strip, temperature and weight. The third system, introduced in our institute at the beginning of 2016, was an EHR (Axigate® version: 5.6.1P9) embedded in the Hospital Information System (HIS). This EHR allows the registration of some other parameters, such as inserting and monitoring a peripheral venous catheter, inserting and monitoring a urinary catheter, providing an inpatient booklet, and monitoring isolation. Finally, the last system, introduced in June 2016, was the Patient Smart Reader (PSR) and was installed in 8 patient rooms (Cohort B).

The PSR system is a personal digital assistant with a barcode scanner that allows for bedside recording of nursing care (https://vimeo.com/205512348). With the PSR, the HCW can record, at the patient's bedside and in real time, nursing care such as the insertion and monitoring of urinary or peripheral venous catheters by using barcoded implements, or the HCW can directly record various parameters such as body temperature, blood pressure or pain directly onto the PSR. The PSR provides automatic reminders of controls or alerts. For example, recording the insertion of a peripheral venous catheter automatically triggers monitoring every 8 hours. The information collected is transmitted to a server that ensures data storage and facilitates data analysis. Reports and alerts are generated by the server and displayed on the main screen that is available in the staff room, as well as on the PSR.

Data collection

First, through a before/after study, we retrospectively compared the compliance of data reported on single sheets of paper from April 2012 to March 2013 (period 1) to that collected in both the Pharma® software and paper sheets from March 2013 to April 2014 (period 2). Then, we compared in a prospective cohort study, from June 2016 to January 2017, the compliance to traceability using our institutional available systems, paper sheets plus Pharma® software and EHR (Cohort A) against the PSR alone (Cohort B). For this purpose, the HCWs were asked to use only the PSR to record care in the eight equipped rooms.

Data analysis

We used descriptive statistics, and we described data compliance in terms of frequencies and percentages. The compliance to traceability (as defined by variable recorded/variable to be recorded) of nursing care using different tools (paper sheet versus paper sheet and Pharma software or any kind of recording systems versus PSR) was analyzed. The obtained differences in compliance were defined as significant when $p<0.05$ (chi-square test). Similarly, the relative risk and a 95% confidence interval were reported.

Variables studied

It was decided to monitor the compliance with traceability of 10 variables selected for their public health impact on the safety of care or their mandatory systematic nature. Some of these acts are mandatory for all patients (welcome inpatient booklet, urine strip, weight once per hospital stay upon patient's admittance, body temperature three times a day, and catheter monitoring when appropriate), but blood cultures, blood and urinary catheter insertion and isolation monitoring were prescribed by a medical doctor.

Inclusion/exclusion criteria

All patients with a length of stay that was less than 5 days were excluded from the study. The length of at least 5 days was chosen to allow a sufficient amount of time in the hospital setting such that a catheter could be prescribed, and other nursing care could be provided as needed.

Ethics

Patients were informed of the study upon being admitted to the unit. They were informed that their participation in the study would not affect their medical care. The study was approved by our independent ethics committee under N° 2018-011.

Results

Medical records for 1532 patients were reviewed, and 732 files were excluded from the study because the length of stay was less than five days. Finally, 800 files were considered suitable for analysis, and 18,455 opportunities were assessed for compliance.

Table 1 summarizes the compliance to traceability of the 10 variables between paper forms (period 1; 407 files) and paper forms plus Pharma software (period 2; 393 files). The paper forms reported a low compliance with traceability; the highest rates were blood catheter monitoring (59.07%) and temperature (58.67%), followed by weight (55.28%), welcome inpatient booklet (46.93%), blood culture (43.66%), blood catheter insertion (32.51%) and isolation monitoring (31%). Urine strip was traced in only 13.51% of cases, and urinary catheter monitoring showed a meager compliance ratio (0.62%). Following the introduction of the Pharma® software, a significant increase in compliance with the traceability of nursing care records was observed for urinary strips, which increased from 13.51% to 19.85% ($p=0.02$), and temperature, which increased from 58.67% to 87.72% ($p<0.0001$). Regarding the other variables, no significant changes were observed, except for a slight but significant decrease in compliance with blood catheter monitoring (59.07% to 56.31%, $p=0.014$).

In the prospective cohort study, a total of 341 files were collected, 148 records were excluded according to the exclusion criteria, and 193 records were included (101 in the cohort A and 92 in the cohort B), thus representing 6,073 opportunities for analysis.

The use of PSR alone significantly improved the compliance with traceability of all nursing care records except for urinary catheter insertion.

Among the essential findings, according to relative risk and 95% confidence interval, blood catheter insertion increased from 44.19% to 100% of prescribed insertion, and blood catheter monitoring rose from 29.64% to 80.74% of catheters monitored. Two other items improved significantly; body temperature increased from 53.12% to 80.81%, and isolation monitoring increased from 26.57% to 43.85% of prescribed isolation (Table 2).

Since then, the system has been deployed in the unit, allowing continuous and real-time monitoring of nursing files. Two years after the completion of this study, the average compliance with traceability of nursing care records of some mandatory items such as temperature, pulse, blood pressure, and pain was 91.7% (Week 7 February 2019), suggesting that the changes in the behavior of healthcare workers have been sustained.

Discussion

Reviews of PDA usage in health care indicate that PDAs are widely used, functional, and useful for documentation. Moreover, PDAs might improve decision making, reduce medical errors, and enhance learning for students and professionals [13,14].

Table 1. Compliance to traceability of 10 variables between papers forms (Period 1) and paper forms plus Pharma software (Period 2).

Nursing care	Period 1 - 407 files			Period 2 - 393 files			RRR (95% CI)	p-value
Variables	To record	Recorded	Compliance (%)	To record	Recorded	Compliance (%)		
Blood catheter insertion	243	79	32.51%	227	82	36.12%	1.11 (0.77-1.58)	0.4669 (NS)
Blood catheter monitoring	4041	2387	59.07%	3717	2093	56.31%	0.95 (0.88-1.02)	0.01484
Urinary catheter insertion	18	3	16.67%	22	5	22.73%	1.36 (0.28-6.49)	0.7089 (NS)
Urinary catheter monitoring	2434	15	0.62%	2237	18	0.80%	1.30 (0.65-2.59)	0.5531 (NS)
Blood cultures	142	62	43.66%	96	44	45.83%	1.04 (0.65-1.67)	0.8433 (NS)
Temperature	6105	3582	58.67%	5895	5171	87.72%	1.49 (1.41-1.58)	<0.0001
Urine strip	407	55	13.51%	393	78	19.85%	1.46 (1.01-2.13)	0.02086
Isolation monitoring	4251	1318	31.00%	3507	1037	29.57%	0.95 (0.86-1.04)	0.1792 (NS)
Weight	407	225	55.28%	393	239	60.81%	1.10 (0.87-1.38)	0.1302 (NS)
Welcome booklet	407	191	46.93%	393	186	47.33%	1.0 (0.78-1.28)	0.9662 (NS)

Table 2. Compliance to traceability of 10 variables between any type of record* (Cohort A) and PSR (Cohort B).

Nursing care	Cohort A - 101 files			Cohort B- 92 files			RRR (95% CI)	p-value
Variables	To trace	Traced	Compliance (%)	To trace	Traced	Compliance (%)		
Blood catheter insertion	43	19	44.19%	31	31	100.00%	2.26 (1.08-4.71)	<0.0001
Blood catheter monitoring	631	187	29.64%	244	197	80.74%	2.72 (2.12-3.49)	<0.0001
Urinary catheter insertion	6	1	16.67%	2	2	100.00%	6.0 (0.33-107.42)	0.1071
Urinary catheter monitoring	88	9	10.23%	92	51	55.43%	5.42 (2.51-11.66)	<0.0001
Blood cultures	63	16	25.40%	26	20	76.92%	3.02 (1.36-6.74)	<0.0001
Temperature	1508	801	53.12%	1188	960	80.81%	1.52 (1.34-1.71)	<0.0001
Urine strip	101	12	11.88%	92	40	43.48%	3.65 (1.80-7.40)	<0.0001
Isolation monitoring	764	203	26.57%	358	157	43.85%	1.65(1.29-2.1)	<0.0001
Weight	101	29	28.71%	92	69	75.00%	2.61 (1.55-4.38)	<0.0001
Welcome booklet	101	27	26.73%	92	68	73.91%	2.76 (1.63-4.68)	<0.0001

*Any type of record: variables recorded on any of the available paper forms plus Pharma® software and electronic medical record

A nursing record system allows the care that has been planned or provided to individual patients by nurses or other caregivers to be recorded. Several studies have already compared paper-based and electronic computerized nursing records and suggest that electronic systems are preferred [15,16]. Nursing record systems may be an effective way of influencing nurse practice. However, with the use of these technologies, nurses are expected to change the way they document patient care by shifting from paper forms to electronic systems. While the documentation of electronic medical records in the presence of the patient likely impacts the nurse-patient relationship [17], in our experience, bedside recording with a barcode allows for nurses and patients to maintain this relationship. Wang et al. reported that the overall quality of the content documented for the nursing process was not better in the electronic system than in the paper-based system [18]. Interestingly, in our study, the addition of a new nursing record electronic system such as Pharma® improved the traceability of body temperature and urine strip recording, but inversely, the new system significantly decreased compliance with blood catheter monitoring. However, in our study, the lack of significant improvement in urinary catheter insertion traceability with the PSR compared to any type of records reported in Table 2 is likely related to the study power.

To avoid information transmission oversights and improve compliance with the traceability of nursing care, it has been suggested that the recording of care should be performed during bedside care. Moreover, the fight against cross-transmission of pathogens in hospitals, resulting in hospital-acquired infection, explains the choice of a dedicated PDA for each bedroom. Among the weaknesses of our study, randomization was not feasible because the health care organization did not allow a random assignment of patients.

To the best of our knowledge, there is no other study reporting the quantitative evaluation of the point of care for nursing records. The advantage of recording at the point of care is twofold. First, recording at the point of care is safer from a hygiene point of view (one PDA per room). Second, recording at the point of care avoids the loss of information between the patient's bedroom and the nearest computer. Moreover, the data collected by the PSR can be directly transferred to the care plan in the patient's electronic files of the hospital information system. We evaluated ten variables because of their mandatory character, but the PSR contains up to 80 variables and allows for decision-making. For instance, once a nurse has registered the introduction of a peripheral venous catheter, the system will ask her if the catheter should be removed during each shift (8 hours).

Conclusion

Post-operative infections, such as central and peripheral venous catheter-related blood stream infections, represent more than half of all AE-related costs. For this reason, we focused our study on the variables associated mostly with hospital-acquired infections rather than drug prescriptions or falls, which are two of the other most frequent AEs reported in the literature. Unfortunately, as the research question focused on the compliance of traceability of nursing care, the adverse events were not recorded. In conclusion, providing a nursing record system to caregivers using barcodes (PSR) at the point of care in real time significantly improved the traceability of nursing care.

Conflicts of Interest

P Brouqui is one of the founders of the Medihandtrace® SAS Startup that owns the copyright of the PSR software.

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Authors' Contributions

Olga Florea designed the study and wrote the paper. S Boudjema, P Brouqui, and JC Dufour wrote the protocol. C Magnin performed the data analysis. JC Dufour contributed his expertise in medical informatics. JC Dufour, S Boudjema and P Brouqui revised the manuscript.

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PARTIE III : Améliorer la surveillance des cathéters par une approche de communication engageante

Préambule

Il est essentiel de comprendre les comportements des soignants afin d'améliorer la qualité des soins. Les soignants ont tendance à façonner leur comportement à partir de leur vécu, de leurs expériences et de leur ressenti. Il est donc compréhensible que l'apport de nouveaux messages de santé publique modifie peu finalement leurs comportements. Le message et donc la communication est un point majeur dans la modification du comportement des soignants. Les techniques de communication engageantes (Binding communication) ont été très développées en France et à AMU, notamment, et appliquées en santé au moment de l'avènement du SIDA. Dans cette partie, nous avons combiné la technologie (PSR) et une approche de communication (**Article 3**).

Nous avons envisagé d'améliorer la qualité de la traçabilité de la surveillance des cathéters veineux périphériques en augmentant le taux d'utilisation du système d'enregistrements des soins infirmiers au lit du patient : Patient Smart Reader® (PSR) en introduisant la communication engageante. Ce travail a été réalisé en collaboration avec Thibault Albertini, doctorant de l'école de journalisme (Aix-Marseille Université, Institut Méditerranéen des Sciences de l'Information et de la Communication). Le paradigme de la communication engageante est à la croisée des théories de l'engagement et de la communication participative. Il est basé sur le principe qu'un individu adopte un comportement non pas en fonction de ses idées mais en raison de comportements déjà réalisés et identifiés concernant le comportement attendu. 12 infirmières ont été invitées et ont participé au protocole de communication engageante pendant 90 vacations de travail. Chez les infirmières on observe une amélioration significative de la compliance à l'utilisation du système d'enregistrements au fil du temps, allant de 27,6 % (IC = [25,3 ; 30,0]) de compliance avant l'intervention à 47,4 % (IC = [45,0 ; 49,9]) après. La communication engageante constitue une méthode efficace pour modifier les comportements des infirmières et améliorer la traçabilité des soins.

Article N°3: Binding communication to improve peripheral venous catheter monitoring.

Albertini Thibaut*, **Florea Bodean Olga*** , Huang Fanyu, Gonin Jeremy, Gaudart Jean, Boudjema Sophia1, Richer Isabelle, Pascual-Espuny Céline, Durampart Michel, Brouqui Philippe

* Equal contribution

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Binding communication to improve peripheral venous catheter monitoring

Albertini Thibaut MS[1,2*] | Florea Bodean Olga RN, MS[1*] | Huang Fanyu PhD[1] | Gonin Jeremy MS[1,3] | Gaudart Jean MD, PhD[3] | Boudjema Sophia RN, PhD[1] | Richer Isabelle RN[1] | Pascual-Espuny Céline PhD[2] | Durampart Michel PhD[2] | Brouqui Philippe MD, PhD[1]

* equal contributions as first authors

[1]AP-HM, IRD, IHU-Méditerranée Infection, MEPHI, Aix Marseille Univ, Marseille, France

[2]Mediterranean Institute for Information and Communication Science, Aix Marseille Univ, Marseille, France

[3]AP-HM, INSERM, IRD, SESSTIM, Hop Timone, BioSTIC, Biostatistics & ICT, Aix Marseille Univ, Marseille, France

Correspondence
Brouqui Philippe, Aix Marseille Univ, AP-HM, IRD, IHU-Méditerranée Infection, MEPHI, Marseille, France.
Email: philippe.brouqui@univ-amu.fr

Pascual-Espuny Céline, Aix Marseille Univ, Mediterranean Institute for Information and Communication Science, Marseille, France.
Email: celine.pascual@univ-amu.fr

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Abstract

Background: Optimizing the monitoring of peripheral venous catheters is essential. We developed a nursing record system at bedside (Patient Smart Reader) to track peripheral venous catheter acts.

Aims: The aim of the present study was to improve peripheral venous catheter monitoring. To improve the quality of monitoring, we aimed to increase the usage of the nursing record system at the bedside.

Methods: We developed a 'commitment intervention' course based on a binding communication paradigm. The corresponding effect on monitoring was analysed using a p-chart and time series analysis.

Findings: Nurses observed a significant improvement in compliance with catheter monitoring over time (shifts after shifts), ranging from 27.6% (CI = [25.3; 30.0]) compliance before the commitment intervention to 47.4% (CI = [45.0; 49.9]) compliance after training. The commitment intervention increased the chances of carrying out monitoring through the tool for acts related to peripheral venous catheters by a factor of 2.42 (odds ratio) (CI = [1.88; 3.11]).

Conclusion: Binding communication provides an effective method for changing nurses' behaviours in terms of safe care. The determinants of engagement (individual vs collective) can be indicators for defining future communication and training strategies in care centers for all health care workers.

KEYWORDS
clinical audit, evaluation, healthcare, experience

1 | INTRODUCTION

The incidence of peripheral venous catheter (PVC)-related bloodstream infections was reported to be 0.1–0.5/1000 catheter-days.[1,2] A prolonged dwell time and catheter insertion under emergency conditions increased the risk of PVC-related bloodstream infection. Approximately 200 million PVCs are inserted into adult patients each year in the United States,[3] and some suggest that based on the literature over 100 000 of these patients become infected with crude and attributable mortality rates of 12.9% and 5.7%, respectively.[4]

Other PVC-related adverse events are not negligible. In the CATHEVAL project,[5] the incidence of PVC-related adverse events was 21.9/100 catheter-days, with infections occurring in 0.4/100 catheter-days. The most prevalent PVC-related adverse events are phlebitis (20.1/100), hematoma (17.7/100), and liquid/blood escape (13.1/100).[5] The rate of phlebitis exceeds 50% by day 4. Replacing or

removing peripheral intravenous catheters as clinically indicated rather than in a set time period of three to four days has recently been suggested.[6]

Consequently, reducing insertion of a PVC and optimizing monitoring to remove such catheters as soon as possible has been shown to be very successful for reducing catheter-related bloodstream infections in the literature.[7,8] However, in routine practice, these guidelines lead to short-term changes only[9] or a nonsignificant reduction.[10] One of the reasons for this nonsignificant reduction is the inappropriate and unsustained monitoring of PVC use. To overcome the lack of monitoring, we developed a nursing record system at bedside using a bar code to trace nursing care called the Patient Smart Reader (PSR); it considerably improves monitoring compared to the standard of care.[11] Consequently, PSR was used to evaluate the performance of nurses monitoring PVC.

To improve adherence to PSR usage in PVC recordings, we conducted an intervention based on binding communication. The binding communication paradigm is at the crossroads of commitment theories and participatory communication. It is based on the principle that an individual adopts a behaviour not because of his or her ideas but because of behaviours already realized and identifiable in regard to the expected behaviour.[12] Work on commitment shows that knowledge has very little influence on our behaviours.[13] An individual's commitment to a behaviour does not depend on his or her knowledge but on behaviours that have already been achieved and linked to the targeted behaviour.[14] Targeted behaviour is the result of a logical sequence of acts for the person who performs them. Actions are therefore linked by the coherence that the individual gives them: 'Why did I not do that? I already did this!'. The justification of the act is reinforced by the realization of a precedent act, reducing cognitive dissonance. Cognitive dissonance is an internal state of tension due to contradictions in mind and beliefs. The human mind naturally attempts to reduce this contradiction. This succession of acts reinforces individuals' commitment, thus favouring the realization of other acts. It is also called a 'cascade of commitment': the more an individual realizes voluntary acts, the more likely he is to do other acts. According to the literature, these behaviours, called 'commitment acts', must also be carried out under specific conditions: they must be easy to do, reiterated, linked and consistent with the final behaviour, and carried out publicly in a context of total freedom without any rewards or punishments.[15-17]

This paradigm can be described in the framework and has already been mobilized to improve behaviour regarding the protection of the environment,[18] organ donation[19] and high-risk behaviours related to HIV transmission,[20] alcoholism,[21] or hospital hygiene and safety of care.[22,23] To our knowledge, this framework has never been applied to improve PVC monitoring or traceability of care. Our aim was to evaluate the impact of binding communication-based interventions on compliance with PSR usage for PVC recordings.

2 | METHOD

To improve adherence to PSR usage for PVC recordings, we developed a specific intervention based on binding communication (commitment intervention) for nurses. Our intervention consisted of leading the nurses to perform a series of commitment acts related to the expected final behaviour (using the PSR for monitoring) to comply with the context's conditions described in the literature. These commitment acts are intended to create a link between what is being done now, what should be done usually, and what will be done afterward. Each commitment act responds to a specific commitment factor (Table 1). For example, nurses were invited to participate in a discussion (commitment act), animated by a trainer, on the interest in and issues related to the tool for monitoring (commitment factors: visibility, cost, etc.). Everyone participated on a voluntary basis. The study was approved by our institutional ethical committee board N° 2016-018.

2.1 | Binding communication

Commitment acts and their associated commitment factors correspond to binding communication guidelines that define conditions for engaging an individual in a behaviour. Consequently, we created different acts that comply with the guidelines. For example, participation in a discussion is considered an action and allows respondents to respond to four precepts: it has a behavioural cost (does something effectively), is visible to other nurses, helps to identify the action level, and reinforces the freedom context. These commitments were selected based on the work published by Burger J.M.[24] and Bernard and Joule[25] and are described in Table 1.

2.2 | Study design and set up

The study was conducted from October 2018 to July 2019 in a medical ward specialized in infectious and tropical diseases at the Institute Mediterranean Infection (IHU) in Marseille, France. Essential information for the design of a study protocol was provided by our experience in anthropology and innovative technologies.[26,27] We designed a mixed-method combining cross-sectional qualitative and quantitative analyses using a p-chart and interrupted time series in a mixed model.

We separated the study into three periods. The total duration of the study was 90 shifts (9 months). The first 30 shifts (period *T*) included basic training on a standard PSR usage procedure. This training was provided to all the nurses and each new nurse joining the ward at any time, but the research protocol provided for updating knowledge by involving all nurses in this initial training. By doing so, all nurses had the same knowledge about PSR use. Then, we observed the nurses in their daily practice for at least 30 shifts to establish baseline PVC monitoring compliance for each nurse. When the last nurse completed the 30 inclusion shifts needed by the protocol, we asked all the nurses in the ward to participate in the study and to sign an informed consent form during a plenary meeting. This signature represented the first commitment act. For the second 30 shifts (Period *T**), at the beginning of this period, we contacted the nurses one by one to establish an availability schedule. We offered them two

TABLE 1 Commitments acts and associated factors selected for the training based on Bernard F and Joule RV[25] and Burger[24]

Part	Acts of HCW	Commitment' Factor
Introduction	listening	Reiterate freedom context
1st part: interest of tracability by tool	Discussion	Behaviour cost
		Visibility from social group
		Action' identification – basal level (« why personal reason i do »)
		Freedom contex (precised orally by the trainer)
	Debate	Behaviour cost
		Reiteration of act
		Visibility from social group
		Internalization of informations
		Freedom context (precised orally by the trainer)
2nd part: problems encountered for tracability by tool	Discussion	Behaviour cost
		Reiteration of act
		Visibility from social group
		Action' identification – lowest level («what i do »)
		Freedom contex (precised orally by the trainer)
		Commitment of institution in increase health quality (precised orally by trainer)
		Pooling of issues
		Collective intelligency
	Debate	Behaviour cost
		Reiteration of act
		Visibility from social group
		Internalization of informations
		Action' identification
		Internalization of informations
		Freedom context (precised orally by the trainer)
3rd part: commitment 'acts realization	Oral classification of acts related to catheters	Link between knowledge and practice
	Filling anonymously summary bulletin	Reiteration of act
		Increase the cost of acts
		Action' identification – highest level (« why the other do what they do »)
		Focus on interest/Rejected of problematics factors
		Freedom context
	Reading summary bulletin by trainer and checking agreement of each HCW	Internalization of acts
		Visibility of agreement y social group
	Social labelling	Positive social mark
	Proposal signature for summary chart of good practice	Irrevocability of acts
		Acceptation of informations
	Proposal to take a badge	Mark the participation to traineeship
		Public visibility

dates that were convenient for everyone. We invited them to participate in a meeting (commitment intervention), stating again that they were free to accept or refuse. We then delivered the "commitment intervention" by group. The last 30 shifts (period *T***) were an observational period to check the sustainability of the intervention. A summary protocol is available in the Grant diagram presented in Figure 1. For reproducibility of the protocol, we created a training guide (Supplementary material) and trained a trainer (RI) to provide the training. The investigators chose to be passive observers of the training.

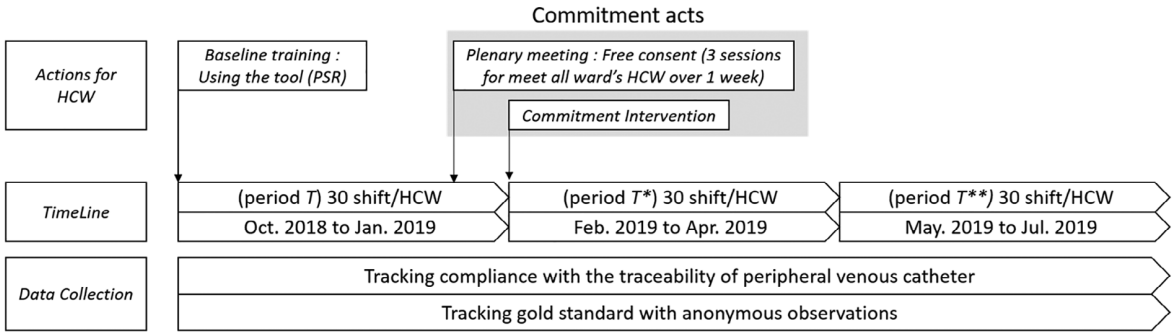

FIGURE 1 Flow chart: Experience Timeline

2.3 | The commitment intervention

The intervention is detailed in the 'training guide' (Supplementary material). To include all participants, two intervention sessions were organized in the same week. In brief, after a short introduction to remind the nurses of their freedom to participate in debates and discussions, they were invited to debate, first, interest in the monitoring tool (PSR) and, second, the problems encountered with it. The trainer made the nurses interact among themselves with the goal of activating commitment factors. The realization of commitment acts was achieved by inviting nurses during a round table to classify acts related to peripheral venous catheters from lowest risk to highest risk, to anonymously complete a bulletin summarizing the three main items of interest in carrying out monitoring with the PSR, to comment in a focus group on the responses recorded in the bulletins and read by the trainer, and to listen to a specific sentence at the conclusion of the training, with the aim of attributing positive social labeling to the nurses before proposing that they sign a unique summary document containing the main issues from the bulletins (Table 1, Supplementary material [A]). This document was displayed in the nurse's office (for visibility of commitment). Finally, we proposed that they wear a badge indicating their commitment (Supplementary material [B]).

On the summary document and the badges, we wrote two sentences: 'I take care of my patients using my PSR®' and 'The monitoring of everyone is safety for all'. These two sentences account for three levels of action identification.[28] Action identification creates a link between what an individual knows and what he or she does. Thus, 'I take care of my patient' responds to a basal level of action with the direct reason, 'I do something because I believe on something'. 'Using my PSR®' is the lowest level. It corresponds to the irreducible physical gesture as 'I do something like this'. 'The monitoring of everyone is security for all' corresponds to the highest level of identification so that the individual can be part of a global and social approach, 'I do something because it must be done'. This last point allows an individual to join an idea socially agreed upon and a social group where some values are shared.

2.4 | Data gathering

To observe PVC act opportunities, we conducted a daily visit to the ward, which was carried out by a PhD student (OF) who recorded when a PVC was inserted, inspected, or removed for each hospitalized patient and which nurse performed the act. PVC recording was established by our developed bedside nursing recording system (PSR), which allows us to record the PVC act (insertion, inspection, and removal) in real time and transmit it to the Meditrace database. PVC act opportunities were entered a posteriori in the same database. Compliance with PSR usage for PVC recording was established from data captured in the database and defined as the ratio of the PVC acts recorded by the PSR divided by the PVC act opportunities.

2.5 | Statistical analysis

We performed a post-intervention analysis on the two successive periods of 30 shifts per nurse after the commitment intervention. The period T^* aimed to observe the impact produced directly at the end of the training and the achievement of a threshold effect. The period T^{**} aimed to observe the sustainability of the training impact over time (Figure 1).

The impact of the commitment intervention on nurse behaviour regarding monitoring catheters was assessed both as a whole for the nurses using a p-chart and as individual behavioural change using time series analysis. A p-chart is a type of control chart of attributes. Here, a p-chart was used to compare compliance with PSR usage for PVC training before and after commitment training for all nurses included in the study. The p-chart describes the temporal evolution of compliance (variables 'shift' – T, T^*, T^{**}) (p) and delimits two control limits. The p-chart was calibrated based on the 30 work shifts for each nurse before the intervention.

For time series analysis, we used a general additive mixed model[29] that considers a nonlinear effect of the number of work shifts and a nonlinear effect of the commitment intervention. This model also considers a random effect of each nurse. The following mixed model was computed with *R Studio Desktop AGPL v. 3*:

$$\begin{aligned} logit\left(P\left(Y_{ij}=1 \mid b_i\right)\right) &\triangleq log\left(\frac{P\left(Y_{ij}=1 \mid b_i\right)}{1-P\left(Y_{ij}=1 \mid b_i\right)}\right) \\ &= \beta_0+\beta_1 T_{ij}+\beta_2 I_{ij}+\beta_3 T^* ij+\beta_4 T^{**} ij+b_i \\ b_i &\rightarrow N(0,\sigma) \end{aligned}$$

where, b_i is the difference between HCWi and the general mean; T is the 30 shifts before the commitment intervention; I_1 is the

commitment intervention indicator; T^* is the 30 first shifts after commitment intervention ($T - t_0$, if $T > t_0$ and $T \leq t_0 + 30$); and T^{**} is the 30 last shifts of the study ($T - t_0 - 30$, if $T > t_0 + 30$)

3 | RESULTS

Of the 14 nurses who signed the consent form, 12 agreed to participate in the commitment intervention. A total of 4376 PVC act opportunities were observed by direct observation (for insertions, inspection, and removal), and 1490 PVC acts were recorded by PSR. The period T runs from October 2018 to January 2019. The period T^* runs from February 2019 to April 2019. The period T^{**} runs from May 2019 to July 2019.

The p-chart (Figure 2) shows that compliance with PSR usage for PVC recordings increased in period T^* and then remained sustainable in period T^{**} (shifts after shifts), going from 27.6% (CI = [25.3; 30.0]) in the pre-intervention period (period T) to 47.4% (CI = [45.0; 49.9]) in the post-intervention period. The impact of the commitment intervention (Figure 2) on compliance was significant ($P < 0.05$). It increased the usage of the PSR for PVC recordings (insertions, inspection, and removals), odds ratio (OR) = 2.42; CI = [1.88; 3.11]. Notably, the change in compliance began after the nurses signed the consent form.

3.1 | Interrupted time series: mixed model

We selected 4 variables: period T: the number of shifts before the commitment intervention; period T^*: the number of shifts between the commitment intervention and the first 30 work shifts after the commitment intervention; the commitment intervention indicator (I)

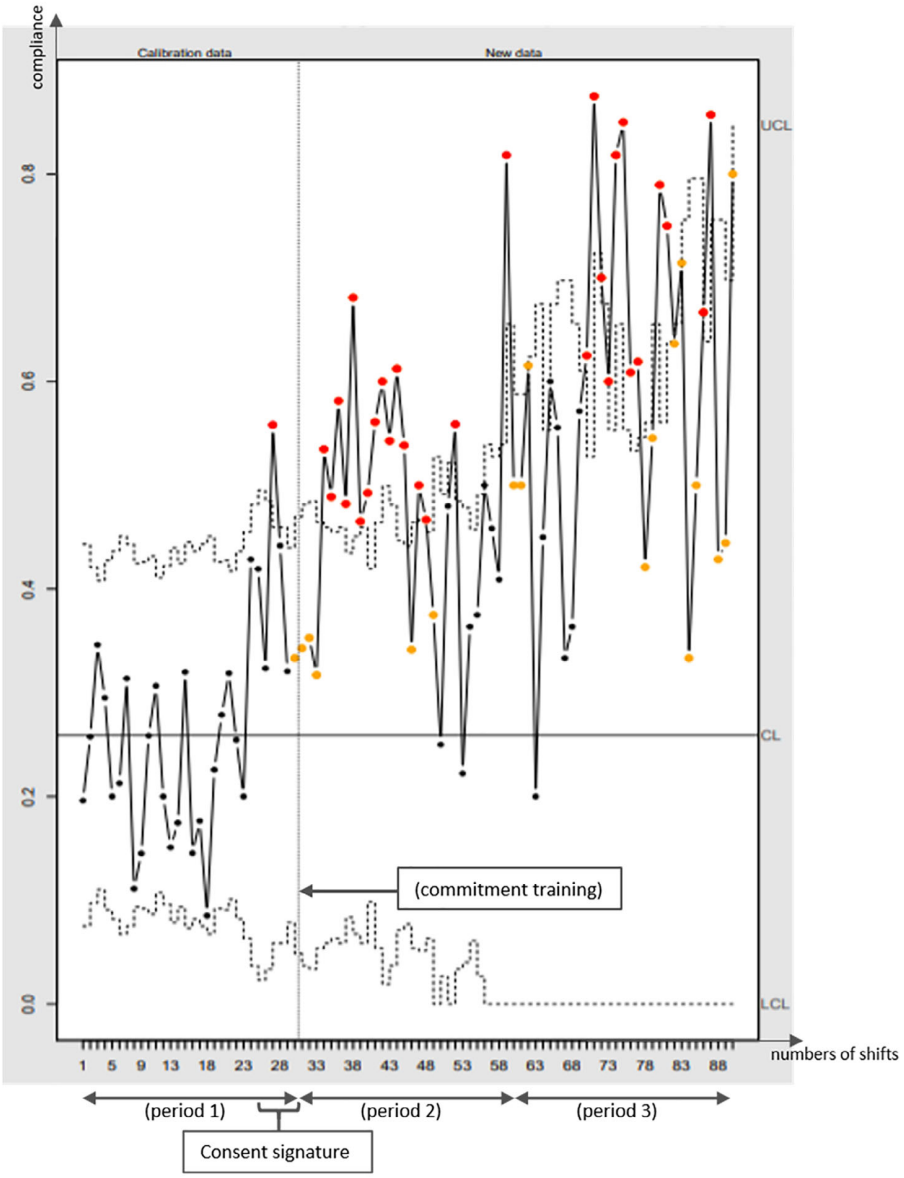

FIGURE 2 P-chart of HCW compliance with monitoring. (period 1) preintervention period, consent form signature, (commitment training) intervention; (period 2) 30 shifts after commitment training; (period 3) last 30 shifts of the study. Dark point: normal values. Yellow point: more than three consecutive points above or below the central limit (CL). Red point: The value is outside the limits of the control card (UCL or LCL)

Variables	Odds ratio	Confidence interval	P-value
(intercept)	0.15	[0.08–0.27]	$P < 0.001$
T (Period 1)	1.03	[1.01–1.04]	$p < 0.001$
I_1 (*commitment training indicator*)	4.12	[2.96–5.73]	$p < 0.001$
T^* (Period 2)	0.99	[0.97–1.00]	$P = 0.044$
T^{**} (Period 3)	0.99	[0.97–1.01]	$P = 0.312$

TABLE 2 Improvement in the odds of monitoring. The binding communication intervention increases the odds to 4.12 (CI [2.96; 5.73])

The shaded values mean the *p*- value was significant.

indicates whether for each act the nurse received the intervention or not; period T^{**}: the last 30 shifts of the study. The results of the binomial logistic regression are summarized in Table 2. Each variable was treated independently.

In period T, each shift worked increased the rates of compliance with PSR usage by OR = 1.03 (CI [1.01; 1.04]), suggesting that there was a small learning effect due to the number of shifts completed (time). The odds ratio for the commitment intervention was 4.12 (CI [2.96; 5.73]), suggesting that the intervention had a strong positive effect on variations in compliance. In period T^*, the odds ratio was 0.99 (CI [0.97; 1.00]), indicating a slowdown in compliance. In period T^{**}, there was no longer any effect induced by time and learning (OR = 0.99; CI [0.97; 1.01]), but the effects were sustained.

We performed the same analysis by adding the type of shift (day/night) as a new variable to the model; there was no significant difference between the types of shift (day/night). The type of shift had no effect on compliance with PSR usage for PVC recordings in our study. The small sample size of nurses included in the study had no influence on the implications of the findings. Indeed, the 12 nurses included in the study produced 4376 acts for PVCs (insertion, monitoring, removal). Our analyses were, therefore, based on this quantity of acts.

4 | DISCUSSION

In our study, all actions were carried out to push the nurses to involve themselves in a cascade of commitment to reach the expected final behaviour and to increase the use of the PSR to track PVC acts. 'The cascade of commitment' is a method that consists of making nurses realize a succession of acts, with the result being 'the more acts they realized, the easier it will be for them to accept doing other acts'. This cascade of commitment led the nurses to reiterate their behaviour, reducing the cognitive dissonance that occurs when a nurse holds contradictory beliefs, ideas, or values or participates in an action that goes against his or her beliefs, ideas, or values.

After the commitment intervention, the PSR usage for PVC recordings increased from 27.6% (CI = [25.3; 30.0]) to 47.4% (CI = [45.0; 49.9]). To the best of our knowledge, there are only three comparable studies in the literature.[22,23,30] They also aimed to modify the behaviour of healthcare personnel to improve care practices. Like us, they appealed to the paradigm of binding communication or psychosocial theories of engagement. Similar to these studies, we show that binding communication is a beneficial way to improve nursing quality. However, only one study assessed the effect of binding communication using an objective measure of behaviour.[22]

Girandola's study reported a small improvement from 10% to 13% in the rate of influenza vaccination coverage in nurses.[22] The other two studies provide an assessment using either direct observation or self-reported practices by participants. Quintard et al. assessed the evolution of representations (how an individual considered a situation or an action). By evaluating and comparing the scores of responses to a questionnaire on preventive gestures, they showed that an intervention, whether engaging or not, had a positive effect on self-reported practices for 61% of their participants. The engaging intervention appeared to produce a significantly stronger effect than the standard condition. The nurses who received standard training seemed to have a better awareness of the reality of the problem of nosocomial infections.[23] Almeida et al. assessed the effect of binding communication on wearing a wedding ring in routine care. They concluded that wearing a wedding ring decreased significantly post-intervention (43% pre-intervention/19% post-intervention).[30] However, this study was based on a self-audit report that was sent to the subjects receiving the intervention. This method leads to biases, most notably social desirability bias. Moreover, for PVC recording, the use of the PSR tool removed the potential Hawthorne effect, which is linked to an observer.

Field observation was conducted in three ways: checking all patients after nurses' visits (and not checking the nurses' work), gathering data collected from nursing handover and nursing records, and PSR database exploitation. Thus, there was no interaction between the investigator (anonymous observer) and the HCW.

Similar to the studies cited above, we tried to respect the theoretical foundations of binding communication.[24,25] Indeed, we were attentive to the framework of freedom of participation, the repetition of commitment acts having a behavioural 'cost', and publicizing (diffusion outside of the nurses' group) and making the acts visible (for others: HCW of the ward and patients hospitalized).

Our study differed in the operationalization of acts and the driving context. To ensure the repeatability and reproducibility of our study, the binding intervention was conducted by a professional care instructor (RI). This singularity is found in the study by Quintard et al[23] She was instructed not to infer information on monitoring in discussions between nurses. In this way, we intended to stimulate reflection by the nurses on the themes predefined in advance (interest

in monitoring care and the problems encountered in its application). Thus, we emphasized the expert knowledge of nurses and let them talk about the problems that they encounter daily in compliance with monitoring. This step was accomplished by emulating collective thinking that is pooling knowledge and individual practices without attempting to persuade.

Like Quintard et al. and Girandola,[22,23] we used a focus group to engage HCWs in behaviours, but instead of inviting HCWs to fill out a questionnaire (knowledge evaluation), we invited them to bring out their experiential knowledge through discussion, debate, and completion of a summary bulletin. We also chose a different method for publicizing. In practice, in the studies by Girandola[22] and Almeida,[30] a chart of commitment was signed. In contrast to our study, such charts were not created with information provided by the healthcare workers during the intervention. In those studies, and in ours, the charts were displayed under the same conditions: in front of the social group in a common place. We chose a last individual brand through a pin badge offered at the end of the training. It had a double interest: to make visible their participation and the commitment made and to serve as a reminder of the individual's commitment.

We question ourselves on the improvements obtained after the end of study. It will be interesting to look at the long-term effects of the study, to know if the effects of the training were kept or if 'booster shots' are necessary to maintain effects and/or increase them again. In period T**, no significant improvement or decline in PSR usage was observed, suggesting that at least for this period, the effect of binding communication was sustained. In our study, binding communication clearly helped to improve the quality of PVC monitoring. The impact on the reduction in bloodstream infection remains to be evaluated.

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DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

ORCID

Florea Bodean Olga https://orcid.org/0000-0002-2367-3596
Huang Fanyu https://orcid.org/0000-0001-7585-7939
Gaudart Jean https://orcid.org/0000-0001-9006-5729
Boudjema Sophia https://orcid.org/0000-0001-6899-9146
Brouqui Philippe https://orcid.org/0000-0002-6125-2805

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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PARTIE IV : L’apport des technologies dans l’exploration de l’hygiène des mains dans les situations à risque de transmission croisée

Préambule

Dans cette partie, nous avons eu l'opportunité de conduire une surveillance de l'hygiène des mains en temps réel pendant un soin à risque.

L'observation directe, recommandée par l'OMS, est considérée comme référence pour évaluer la compliance à l'hygiène des mains. Toutefois, cette méthode est coûteuse en temps et biaisée à cause de l'effet Hawthorne. Les systèmes électroniques de surveillance de l'hygiène des mains se développent et sont considérés comme plus fiables que l'observation directe pour la surveillance de l'hygiène des mains. Cependant, aucun n'est en mesure d'évaluer la conformité dans les soins infirmiers complexes. Pourtant il paraît légitime de focaliser la surveillance sur les gestes les plus à risque de transmission. Pour contourner ces limitations, un système de surveillance automatique de l'hygiène des mains a été développé (Médihandtrace®) (**Annexes 3-4**). Cette méthode permet d'observer la compliance à l'hygiène des mains en temps réel avec géolocalisation sans intervention humaine et de recueillir des données en continu au fil du temps. Afin d'optimiser l'exploration de l'hygiène des mains dans les situations à risques de transmission croisée, nous avons combiné cette méthode avec l'outil de traçabilité de soins (Patient Smart Reader) (**Annexes 5).** Les tâches infirmières ont été classées comme procédure de tâches standard ou procédure de tâches aseptiques correspondant au Moment 2 parmi les 5 moments d'hygiène des mains recommandés par l'OMS. Toutes les analyses statistiques ont été réalisées à l'aide de R, version 3.6.2. Pour les modèles mixtes, le package « lme4 » a été utilisé.

À partir de la base de données fusionnées au cours de la période d'étude de 2 ans, 30 164 tâches infirmières ont été identifiées pour analyse, 25 633 ont été classées comme procédures de tâche standard et 4 531 ont été classées comme procédures avec tâche aseptique de soins infirmiers. La désinfection des mains avec une solution à base d'alcool n'a pas été détectée avec notre système dans 42,50 % de toutes les tâches enregistrées, 37 % de toutes les procédures de tâches aseptiques et 47,1 % de toutes les procédures de tâches standard pour les soins infirmiers ($p = 0,0362$), indiquant que le moment 2 de l'OMS n'était pas respecté dans

37% des situations obligatoires.

Cette étude a montré qu'à l'aide d'une combinaison de différentes technologies, nous avons pu évaluer les performances d'hygiène des mains dans les circonstances les plus risquées.

Article N°4: Internet of Things (IOT) To Explore the Moment 2 of "WHO My Five Moments" For Hand HYGIENE

Olga Florea, Jeremy GONIN, Hervé TISSOT-DUPONT,

Jean-Charles DUFOUR, Philippe BROUQUI and Sophia BOUDJEMA

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Internet of Things to Explore Moment 2 of "WHO My Five Moments" for Hand Hygiene

Olga Florea[1], Jeremy Gonin[2], Hervé Tissot Dupont[1,2], Jean Charles Dufour[3], Philippe Brouqui[1,2] and Sophia Boudjema[1]**

[1] Aix Marseille Université, IRD, MEPHI, IHU-Méditerranée Infection, Marseille, France, [2] AP-HM, IHU-Méditerranée Infection, Marseille, France, [3] Aix Marseille Université, AP-HM, INSERM, IRD, SESSTIM, Hop Timone, BioSTIC, Marseille, France

Background: Electronic hand hygiene surveillance systems are developing and considered to be more reliable than direct observation for hand hygiene monitoring. However, none have the capability to assess compliance in complex nursing care.

Materials and Methods: We combined two different technologies, a hand hygiene monitoring system (radiofrequency identification, RFID) and a nursing care recorder at the bedside, and we merge their data to assess hand hygiene performance during nursing. Nursing tasks were classified as standard task procedures or aseptic task procedures corresponding to moment 2 among the five moments for hand hygiene recommended by the WHO. All statistical analyses were performed using R, version 3.6.2. For mixed models, the package "lme4" was used.

Results: From the merged database over the 2-year study period, 30,164 nursing tasks were identified for analysis, 25,633 were classified as standard task procedures, and 4,531 were classified as aseptic task procedures for nursing care. Hand disinfection with an alcohol-based solution was not detected with our system in 42.5% of all the recorded tasks, 37% of all the aseptic task procedures, and 47.1% of all the standard task procedures for nursing ($p = 0.0362$), indicating that WHO moment 2 was not respected in 37% of mandatory situations.

Conclusion: Using a combination of different technologies, we were able to assess hand hygiene performance in the riskiest circumstances.

Keywords: hand hygiene (disinfection), IoT - internet of things, five moments for hand hygiene, nosocomial infections, catheter - complications

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Dario Salvi,
Malmö University, Sweden

Reviewed by:
Ivan Miguel Pires,
Universidade da Beira Interior, Portugal
Palash Chandra Banik,
Bangladesh University of Health Sciences, Bangladesh

***Correspondence:**
Sophia Boudjema
sophia.boudjema@hotmail.com
Hervé Tissot Dupont
herve.tissot-dupont@ap-hm.fr

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INTRODUCTION

It is generally believed that hand hygiene reduces the prevalence of hospital-acquired infections (HAIs), and that inadequate hand hygiene is one of the main risk factors for infection (1–4).

The risk of transmission of microbes from the hands of healthcare workers (HCWs) to patients has been studied extensively in peripheral venous catheters (PVCs), which have long been associated with infection (4–6).

Appropriate hand disinfection prior to PVC insertion significantly reduces the incidence of infection (5–8). Direct observation is the current gold standard to appreciate compliance to hand hygiene. A model of transmission identifying moments at which healthcare workers (HCWs) are at

risk for transmission has been suggested (9). This model was used to develop "My Five Moments for Hand Hygiene" (10, 11). Alcohol-hand-rub (AHR) with an alcohol-based solution before moments 1 and 2 is suggested to prevent the transmission of infection to patients, whereas AHR after moments 3, 4, and 5 is suggested to protect the environment of patients and the transmission of infection to other patients. Moment 2 of the My Five Moments by the WHO is defined as hand disinfection before an aseptic task procedures (12). While Moment 2 appears as a very important clue to cross transmission, its monitoring by direct observation is difficult as events are relatively infrequent compared with moments 1 and 5.

To bypass this difficulty, we have developed a tool to record the task of a nurse at the bedside of the patient that we called patient smart reader (PSR) (13). This personal digital assistant allows to record nurses care at the bedside and send data in a centralized database connected to hand hygiene monitoring system and available for nurse's feedback in real time.

An automated hand hygiene monitoring system has recently been developed with the aim to replace direct observational monitoring, because it avoids the influence of the Hawthorne effect and appears to be more reliable (14–16). Since 2012, we have developed an automated hand hygiene monitoring system and used it as a part of the HAI Management at the University Hospital Institute Méditerranée Infection (IHU-MI) (17–19). However, to our knowledge, there are no automated hand hygiene monitoring systems that allow for the evaluation of hand hygiene before an aseptic task procedure (moment 2), except for remote video-based surveillance systems, which are time-consuming and not cost-effective (20, 21).

This study aimed to evaluate the hand hygiene of nurses before an aseptic task procedure (moment 2) using merge data provided by our automatic hand hygiene monitoring system coupled with the PSR. The hand hygiene monitoring system provided alcoholic hand rub use and entry/exit of the bedroom, and the PSR provided information on the nature of the nursing task recorded during care. This way, we investigated if nurses performed ARH during care and for which kind of care.

MATERIALS AND METHODS

Electronic Survey

For this study, we used a combination of data from two different electronic data capture (EDC) systems (see functional schema in **Supplementary Material**). An EDC system is a computerized system designed for the collection of clinical data in electronic format for use mainly in human clinical trials. The first EDC system was a hand hygiene automated electronic system named MediHandTrace® (MHT), which is an RFID (13.56 MHz)-based personal identifying tracking system that records compliance to AHR for each identified HCW. This system was deployed in a 25-bed infectious disease ward in Marseille, France (18). MHT detects the movements of HCWs by tracking chips that are placed in the shoes of HCWs; RFID signals are emitted by an antenna placed on the floor at the entrance of the bedroom. When an HCW enters the room by opening the door, the device is triggered, and a set of signals are captured and stored in a server at the following time points: [0] when the door opens, [1] when the HCW walks near the antenna, [2] when the HCW walks out of the range of the antenna, and [8] when AHR is performed within or [10] more than 8 s after the HCW enters the room. The second EDC system was a handy personal digital assistant with a barcode reader named the Patient Smart Reader (PSR), a device that allows to record, at patient bedside, nursing tasks. This tool allows for integration of recorded data within the SQL database stored in the PSR, and are then synchronized with a desktop- or server-based database. It allows nursing care tasks and vital signs of patients to be recorded by HCWs in real time during the provision of care (note that an HCW can record the action before or after he/she performs it) (13). This is an important limitation, which explains that only the lack of compliance to AHR can be explored. If AHR is performed, we cannot identify if this is before (good) or after (bad) the task. To record a task, an HCW must identify himself or herself, identify the patient, and identify the task by scanning the barcode affixed to the wall next to the bed. Both systems (MHT and the PSR) are time-synchronized and send the collected data on the same server using a unique ID for each HCW. Together, these two systems enable hand hygiene assessment performed at the time of a specific nursing task.

Selection of Variables

The nursing tasks that were explored are listed in **Table 1**. They were classified as standard task procedures (STPs) or aseptic task procedures (ATPs) corresponding to moment 2 for hand hygiene. Each act recorded in a designated aseptic task should be associated with one AHR (hand hygiene opportunity). The lack of compliance to AHR is defined by the ratio of no AHR/number of acts in the designated task.

Data Analyses

The data used for the study were extracted from the raw data (MHT database and PSR database) collected from January 11, 2017 to January, 11, 2019. The lack of compliance during ATPs was compared with the lack of compliance during STPs. Both systems have been used in the ward for years, and HCWs were invited to participate in the study as part of their natural nursing routine. No specific training was given before the study.

Statistical Analysis

All the statistical analyses were performed using R, version 3.6.2. For the mixed models, the package "lme4" was used. For all the statistical tests, the alpha risk level was set to 5%, and a bilateral alternative hypothesis (two-sided test) was used, except when the Kolmogorov–Smirnov test was performed with a unilateral alternative hypothesis (one-sided test). The lack of compliance with hand hygiene was compared across durations by the chi-square test.

In a previous study, we reported that the use of an automated electronic surveillance system generated a large amount of data for which the bias in the relationship between HCW activity and HCW performance with AHR was needed to be corrected using a multilevel multivariate logistics model (18). To better control the link between hand hygiene compliance and the type

TABLE 1 | Ratio of lack of compliance to hand hygiene among 30,164 categorized nursing tasks as surveyed by electronic monitoring system.

Nursing task	NO AHR*	Total acts	(%)	Task category
Final household	139	200	69.5	STP
Patient departure	1,076	1,729	62.2	STP
Meal stimulation	92	177	52.0	STP
Vital signs recording	5,461	10,722	50.9	STP
Drinking stimulation	152	304	50.0	STP
Care of eschars	59	119	49.6	ATP
Meal aid	115	235	48.9	STP
Penile case pose	13	27	48.1	STP
Diet collation	12	25	48.0	STP
Prevention of eschars	468	1,003	46.7	STP
Refurbishment of the bed	525	1,145	45.9	STP
Layer Pose	646	1,416	45.6	STP
Eyes care	163	358	45.5	STP
Drink aid	129	285	45.3	STP
Mouth care	183	405	45.2	STP
Dressing maintenance	150	334	44.9	ATP
Meal installation	164	367	44.7	STP
Changing diaper	565	1,272	44.4	STP
Chair installation	72	163	44.2	STP
Exchange urine pouch	32	75	42.7	STP
Removal dressing	54	127	42.5	ATP
Removal penile case	14	33	42.4	STP
Patient toilet	234	569	41.1	STP
Emptying urine pouch	93	227	41.0	ATP
Urinary catheter monitoring	168	419	40.1	ATP
Blood Catheter monitoring	653	1,753	37.3	STP
Blood Catheter Removing	144	391	36.8	ATP
Sub cutaneous medication	239	659	36.3	ATP
Per os medication	867	2,391	36.3	STP
Urinary catheter insertion	17	47	36.2	ATP
Dressing Pose	58	163	35.6	ATP
Blood infusion transfusion	8	23	34.8	ATP
Blood culture	41	118	34.7	ATP
Intravenous medication	360	1,042	34.5	ATP
Blood test collection	180	524	34.4	ATP
Blood Catheter insertion	93	292	31.8	ATP
Urinary catheter removing	14	46	30.4	ATP
Daily housekeeping	288	953	30.2	STP
Penile case watch	7	26	26.9	STP
Total		30,164		

Lack of compliance is defined as no alcoholic hand rub (NO AHR)/ number of dedicated acts recorder with PSR.
**No alcoholic hand rub for task recording.*
STP, Standard task procedure; ATP, Aseptic task procedure.

of nursing care, the following generalized linear mixed models were formulated:

$$M_0 : logit\left(P\left(Y_{ij}=1\right)\right)=\beta_0$$

$$M_{0r} : logit\left(P\left(Y_{ij}=1\right)\right)=\beta_0+\ b_{0i}b_{0i}\sim N\left(0,\sigma_0^2\right)$$

$$M_1 : logit\left(P\left(Y_{ij}=1\right)\right)=\beta_0+\beta_1X_{ij}$$

$$M_{1r} : logit\left(P\left(Y_{ij}=1\backslash b_{0i}\right)\right)=\beta_0+\beta_1X_{ij}+b_{0i}b_{0i}\sim N\left(0,\sigma_0^2\right)$$

where Y is the hand hygiene compliance variable (Y = 0 if AHR is not used and Y = 1 if AHR is used) and X is the nursing task risk variable (X = 0 if the nursing task is an STP and X = 1 if the nursing task is an ATP). The index i represents the HCW level, j represents the nursing care level, and Y_{ij} represents hand hygiene compliance. The different models

were compared using several methods. The Akaike inference criterion (AIC) was used when the models were not nested. For the nested models, comparisons were made with the likelihood ratio test corrected for the comparison between two mixed models. For the models with random effects, the intraclass correlation coefficient (ICC) was used to measure the percentage of variance in AHR use attributable to HCW level. The ICC was estimated based on assumptions for binary variables, and the variance attributable to the HCW level was divided by the total estimate variance. For the models without random effects, the estimations were maximum-likelihood estimations, and for the mixed models (with random effects), the maximum-likelihood estimation method with Laplace approximation was used. Finally, to investigate when AHR was performed within the care sequence, the distribution of hand hygiene within the care sequences was compared between the STPs and ATPs for nursing. The duration of each care sequence was split into 100 intervals of the same length, and the significance was tested by the Kolmogorov-Smirnov test with a unilateral alternative hypothesis (**Supplementary Material**). The data set is available upon request to the corresponding author.

Ethics

To ensure the anonymity of the data analyzed, a random number was assigned to the data from each participant included in the database. All the procedures for this study were approved by the Ethics Committee of our institution (N° 2016-018). Before the study, the HCWs were informed of the details of the study and they gave their consent to be monitored by the automated systems.

RESULTS

Among 39 nursing procedures, 24 were classified as standard task procedures (STPs) and 15 were classified as aseptic task procedures (ATPs) for which ARH before the procedure is mandatory (Moment 2). The most frequent procedures, such as recording of vital signs, per os medication, and layer pose were STPs. Among the ATPs, blood catheter monitoring, intravenous medication, and blood test collection were the most frequent. Our system identified the HCW in the patient room for 30,164 nursing tasks procedures during the 2-year study period. Of the 30,164 tasks, 25,633 were classified as requiring STPs for nursing, and 4,531 were classified as requiring ATPs for nursing (**Table 1**).

No AHR was detected in 42.5% of all the tasks, 37% of the ATPs, and 47.1% of the STPs for nursing ($p = 0.0362$), indicating that moment 2 was not respected in 37% of the mandatory situations. For the ATPs, the nurses performed better than the assistant nurses (35.9 vs. 51.6% of lack of compliance to M2; $p < 0.001$). The assistant nurses practicing STPs did not perform AHR at all in 52% of these nursing tasks. The housekeeping workers only performed STPs, and AHR was not detected in 40.6% of the tasks. Among the nursing tasks performed, those with lower lack of AHR execution was urinary catheter removal, blood catheter insertion, blood sample collection, intravenous medication, and blood cultures (**Figure 1**). Interestingly, some tasks that were considered STPs for nursing, such as penile case assessments and per-os medication, were associated with higher AHR performance. **Figure 2** shows the distribution of AHR events among 16,416 nursing tasks, 12,759 classified STPs (in gray), and 2,853 ATPs (in black) during the nursing task. Hand hygiene is more frequently performed at the end of the task when STPs nursing is performed (Kolmokorov–Smirnov 0.84 $p < 2.2$ E-16). In ATPs nursing the AHR is performed in a similar way upon entry rather than upon exit. A multilevel analysis showed that the variables associated with AHR were the behavior of HWCs itself and the nature of the tasks. AHR was slightly performed more often by any of the HCWs when the task recorded was an ATP [ORa 1.08 (95% CI) (1.01–1.17) $p = 0.036$] (**Supplementary Material**).

DISCUSSION

Electronic hand hygiene systems have been developed not only to record but also to promote compliance. These systems have been designed to ensure that HCWs perform hand hygiene before approaching the patient's bedside (M1) and to issue an alert for HCWs to do so (18). Despite their advantages, newer technologies, at this time, are unable to differentiate the five moments for hand hygiene, but most of them can detect whether the hands of HCWs have been disinfected before touching a patient (moment 1) and before leaving the patient zone (similar to moments 3, 4, and 5). Nevertheless, the level of risk of infection is associated with specific steps in the care process and the relative importance of hand hygiene at each of the five moments in preventing microbial transmission and infection outcomes is still unknown (22). According to the WHO guidelines, it is assumed that "an ideal indicator of hand hygiene performance would reliably capture each moment requiring hand hygiene, even during complex care activities" (20). In this study, by merging the data obtained from the two systems, we successfully identified that in ATPs that are identified as high risk for cross-transmission of microbes to patients, no ARH was performed in 37% of the tasks. However, this lack of compliance may be underestimated. Among task for which we detect AHR it is possible that hand hygiene was performed after the aseptic procedure as reported in **Figure 2**, and consequently considered as inefficient. This is the main limitations of our study.

The lack of AHR among the nurses practicing ATPs is likely related to the fact that they have reduced the need for hand hygiene by wearing non-sterile gloves, which can make HCWs feel less exposed to dirt and microbes, and protected against blood-borne diseases (20). The overuse of gloves has been shown to be one major factor explaining poor hand hygiene compliance (23, 24). There is currently increasing scientific evidence that glove disinfection is as effective in preventing infections in experiments as in routine care, and that glove disinfection should be promoted (25, 26). Recently, Fehling et al. reported that allowing glove disinfection significantly improved hand disinfection, particularly at moment 2, and reduced the occurrence of severe infections considerably (27). The weakness of our system is that we detect the lack of

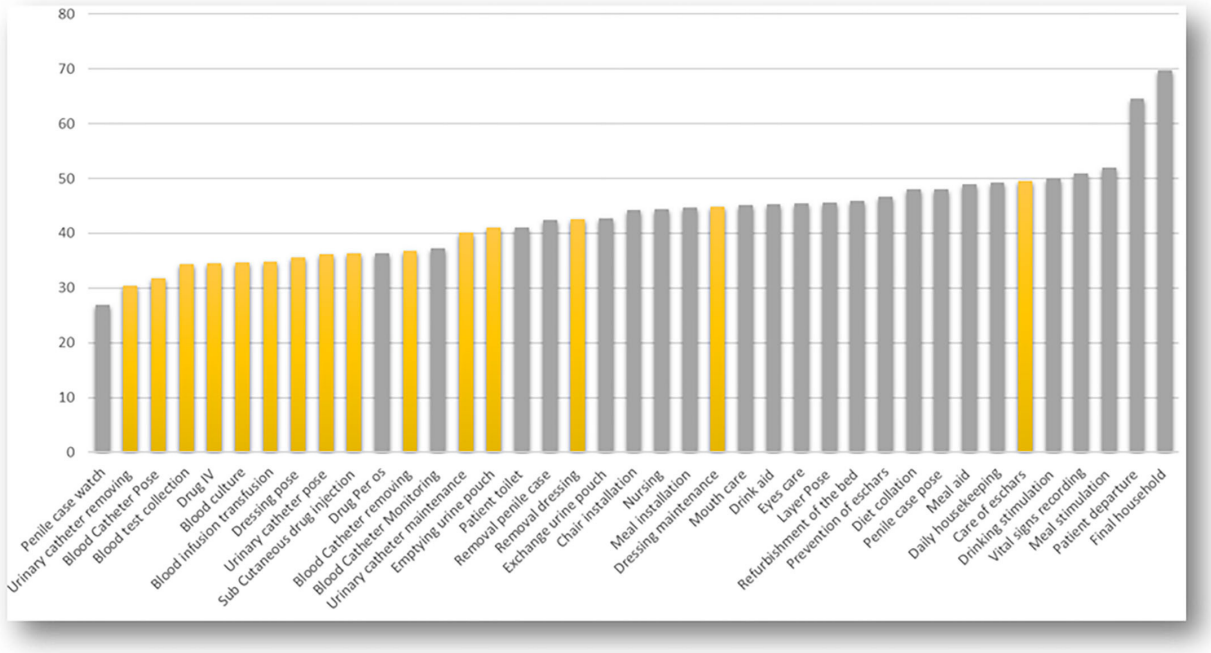

FIGURE 1 | Distribution of lack of compliance (%) to hand hygiene in aseptic task procedure (WHO Moment 2) vs. standard task procedure nursing. Hand hygiene is better performed when the nursing is in the category aseptic task (yellow) compare to standard precaution (gray) that were 1,678 (37%)/12,070 (47.1%) $p < 2.2$ E-16.

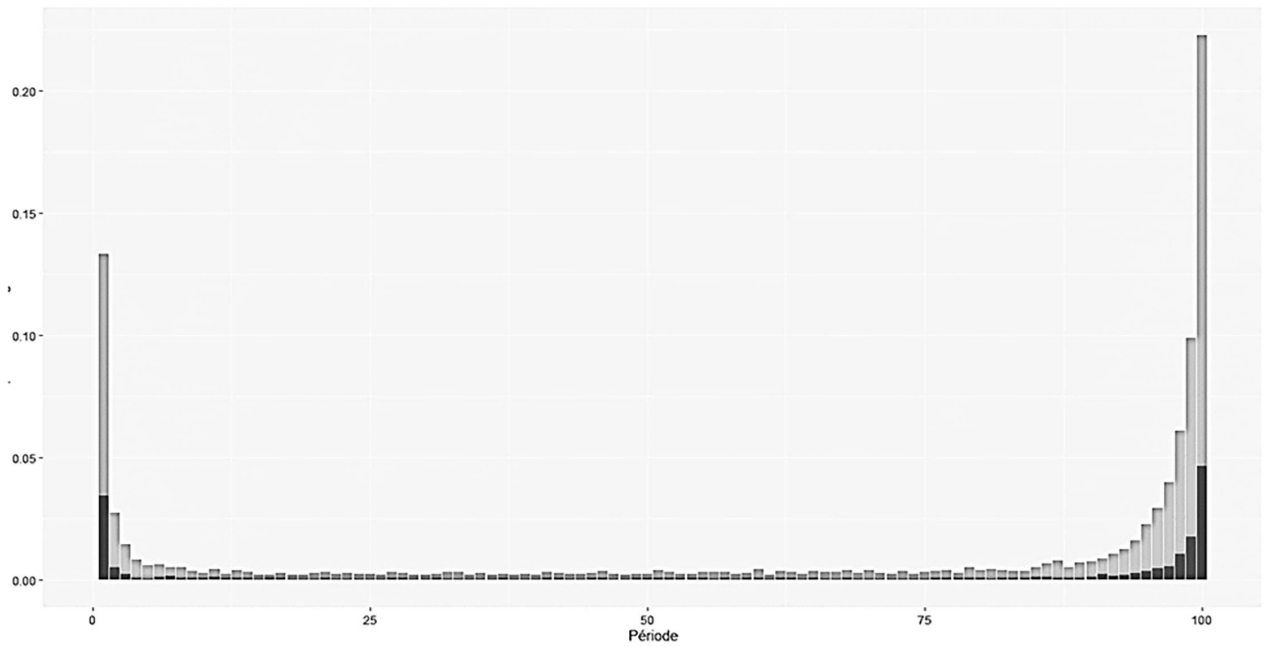

FIGURE 2 | Distribution during the nursing task (from room entry to room exit) of alcoholic hand rub among 16,416 nursing tasks, 12,759 classified standard task procedures STP (in gray) and 2,853 aseptic tasks procedures ATP (in black). Hand hygiene is more frequently performed at the end of the task when standard task procedure nursing is performed (Kolmokorov-Sirnov 0.84 $p < 2.2$ E-16). In aseptic task procedure nursing the AHR is performed in a similar way at entry that at exit.

AHR, but the technology available at this time is unable to detect AHR and whether it occurs precisely within the time of nursing. Only video capture is capable of doing it. A new generation of hand hygiene monitoring should evolve to dematerialized video system with real time data analysis and feedback.

In conclusion, assessing hand hygiene surveillance during complex care is feasible by combining different technologies. Although not perfectly responding to WHO requirements for an ideal indicator, this proof-of-concept study reveals that AHR is not performed in at least 37% of care situation for which it is mandatory. Focused interventions on the practice of moment 2 for hand hygiene should be quicky implemented and then evaluated.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

This study has been approved by the Ethical Review Board of IHU Mediterranée-Infection under N° 2016-018.

AUTHOR CONTRIBUTIONS

PB, JD, and SB conceived and designed the experiments. OF performed the experiments. OF, JG, and SB analyzed the data. OF, JG, and PB wrote the manuscript. OF, JD, and SB edited the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fdgth.2021.684746/full#supplementary-material

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Conflict of Interest: PB owned part of the start-up company MedihandTrace SAS, which commercialized the electronic monitoring system.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Table 2: Variable associated with hand hygiene.

Multi-level logistic analysis (N=46 HCWs)	Nursing tasks (N=30,164, Ref = no AHR use)				
	N(%)	Null mixed model (M_{0r})		Full mixed model (M_{1r})	
		ORa (95% CI)	P value	ORa (95% CI)	P value
Fixed effect					
Individual adjusted OR	-	0.97 (0.67-1.39)	0.881	0.96 (0.68-1.36)	0.837
Type of nursing tasks	25633 (85.0)	-	-	1	-
STP	4531 (15.0)	-	-	1.08 (1.01-1.17)	0.036
ATP			-		-
Random effect		1.389	-		-
Interindividual variance	-	0.30		1.385	
ICC	-		-	0.30	-
Statistical model	-	38047.4	-		-
AIC	-	38064.0	-	38045.0	-
BIC	-	-19021.7	-	38069.9	-
logLik				-19019.5	
Deviance		38043.4		38039.0	

STP – standard task procedures; ATP – aseptic task procedures
AIC -**Akaike** information criterion
BIC - Bayesian information criterion
logLik - natural logarithm of the likelihood
ORa (95% CI) - Odds Ratios (OR)a and **95% Confidence Intervals (CI)**

In order to studies the link between the hand hygiene compliance and the type of nursing act, the following generalized linear mixed models were built:

$$M_0 : logit\left(P(Y_{ij} = 1)\right) = \beta_0$$

$$M_{0r} : logit\left(P(Y_{ij} = 1)\right) = \beta_0 + b_{0i} \qquad b_{0i} \sim N(0, \sigma_0^2)$$

$$M_1 : logit\left(P(Y_{ij} = 1)\right) = \beta_0 + \beta_1 X_{ij}$$

$$M_{1r} : logit\left(P(Y_{ij} = 1 \backslash b_{0i})\right) = \beta_0 + \beta_1 X_{ij} + b_{0i} \qquad b_{0i} \sim N(0, \sigma_0^2)$$

Where Y is the hand hygiene compliance variable (Y=0 if no AHR use and Y=1 if AHR use) and X is the nursing act risk variable (X=0 if the nursing act is a SPP act and X=1 if the nursing act is a ATP act). The indice i represents the HCW level and j represents nursing care level, then Y_{ij} represents the hand hygiene compliance for the j th nursing act from the i th HCW.

The different models were compared between them, by several methods. The Akaike Inference Criterion (AIC) was used when models are not nested. For nested models, the comparison was made with likelihood ratio test corrected for comparison between two mixed models

$M_0 \subset M_{0r} \subset M_{1r}$ $M_0 \subset M_1 \subset M_{1r}$

	M_0	M_{0r}	M_1	M_{1r}
Deviance	41580	38043.4	41421	38039.0
AIC	41582	38047.4	41425	38045.0

Comparison between M_0 and M_{0r} : LR = Dev(M0) – Dev(M0r) = 41580 – 38043.4 = 3536.6 ($p < 0.0001$)

Comparison between M_0 and M_1 : LR = Dev(M0) – Dev(M1) = 41580 – 41421 = 159 ($p < 0.0001$)

Comparison between M_1 and M_{1r} : LR = Dev(M1) – Dev(M1r) = 41421 – 38039.0 = 3382 ($p < 0.0001$)

Comparison between M_{0r} and M_{1r}: LR = Dev(M0r) – Dev(M1r) = 38043.4 – 38039.0 = 4.4 (0.0359)

The selected model after comparison is the M_{1r} model. There is an effect of the nursing act risk variable on the hand hygiene compliance despite existence of individual variation.

Table 2 : Variable associated with hand hygiene

Multi-level logistic analysis (N=46 HCWs)	Nursing acts (N=30164, Ref= no AHR use)				
	N(%)	Null mixed model (M_{0r})		Full mixed model (M_{1r})	
		ORa (95% CI)	P	ORa (95% CI)	P
Fixed effect					
Individual adjusted OR	-	0.97 (0.67-1.39)	0.881	0.96 (0.68-1.36)	0.837
Type of nursing acts	25633 (85.0)	-	-	1	- 0.036
SPP	4531 (15.0)	-	-	1.08 (1.01-1.17)	-
ATP			-		-
Random effect		1.389	-		-
Interindividual variance	-	0.30	-	1.385 0.30	-
ICC	-	38047.4	-		-
Statistical model	-	38064.0	-	38045.0	-
AIC	-	-19021.7	-	38069.9	-
BIC	-	38043.4		-19019.5	
logLik				38039.0	
Deviance					

PARTIE V : L'apport des approches innovantes dans la compréhension d'amélioration des soins

Préambule

MediHandTrace® permet d'enregistrer automatiquement la désinfection des mains, mais il ne permet pas de déterminer l'enchainement des gestes dans la pratique de soins. Nous avons alors voulu observer les pratiques d'hygiène au quotidien et lors de soins complexes. Nous nous sommes donc intéressés aux comportements des soignants lorsqu'ils étaient en routine de soins et avons utilisé une deuxième fois la vidéo. Les soignants étaient filmés en routine de soins. L'étude a montré que les soignants se désinfectaient les mains au moins une fois lors d'un parcours de soins ce qui représentait 28,5% des situations. La friction hydroalcoolique avant d'entrer dans la chambre et de sortir de la chambre du patient n'était respectée que dans 6,2% des cas. Le port des plateaux-repas était associé à une faible désinfection des mains. Enfin dans le cas où les soignants devaient prendre des précautions complémentaires d'hygiènes du type Clostridium difficile, nous avons mis en évidence le non-respect des protocoles [17] . L'adhérence au port du gant est de 51,2% dans la précaution de contact Clostridium difficile, et la conformité au protocole est de 17,5%. Aussi l'étude met en évidence que le port de gants nuit à la désinfection des mains, surtout lorsque les gants ne font pas partie du protocole (38,7%). L'adhérence au port du masque en cas de précaution aéroportée est de 90.7% (Article 5). Un retour de l'étude a été effectué auprès des soignants leur montrant la nécessité et l'importance de l'hygiène des mains d'autant plus lorsque les patients sont porteurs d'infections hautement contagieuses et résistantes. Des formations régulières par un membre de l'équipe opérationnelle d'hygiène hospitalière ont été menées par la suite.

Article N°5: Hand Hygiene Analyzed by Video Recording

Sophia Boudjema, Pauline Reynier, Jean Charles Dufour, **Olga Florea**, Philippe Patouraux, Patrick Peretti-Watel and Philippe Brouqui

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Research Article Open Access

Hand Hygiene Analyzed by Video Recording

Sophia Boudjema[1,2#], Pauline Reynier[3#], Jean Charles Dufour[3,4#], Olga Florea[2#], Philippe Patouraux[3], Patrick Peretti-Watel[3,5#] and Philippe Brouqui[1,2#*]

[1]Aix Marseille Université, URMITE, UM63, CNRS 7278, IRD 198, Inserm 1095, Marseille, France
[2] Infectious Disease Unit CHU Nord, Assistance Publique des Hôpitaux de Marseille, France
[3]Aix Marseille University,UMR912 SESSTIM (AMU-Inserm-IRD-AMSE), Marseille, France
[4]BIOSTIC, Pôle de Santé Publique, Assistance Publique des Hôpitaux de Marseille,
[5]ORS PACA, Southeastern Health Regional Observatory, 13006, Marseille, France
[#]Institut Hospitalo Universitaire IHU Méditerranée Infection

Abstract

Objective : The aim of this study is to evaluate the hand hygiene and isolation precaution adhesion of the healthcare workers in routine cares.

Methods : In an infectious diseases care unit of a university hospital in Marseille, France, we designed an observational study at evaluating the hand hygiene and isolation precaution adhesion of the healthcare workers in routine cares by remote video recording. The care team including nurses, assistant nurses, housekeepers and physicians was monitored from November 30th (2012) to February 13th (2013). From a video camera was placed inside patient room, healthcare workers paths were recorded from entrance to exit of the patient's room. Hand hygiene disinfection as well as gloves and mask wearing in isolation precautions were observed. A video camera was placed inside patient room. Healthcare workers paths were recorded from entrance to exit of the patient's room. A nurse and a sociologist analyzed further videos. Hand hygiene disinfection as well as gloves and mask wearing in isolation precaution were observed.

Results : A total of 756 videos were captures. 249 were rejected because they were not contributive and 507 videos (811 Healthcare workers paths) were analyzed. Healthcare workers had hand disinfection at least one time in the path in 28.2%. Hand disinfection at entrance and exit of the bedroom is respected in 6.2%. The meal tray delivery is associated with a lower hand hygiene practice. The glove wearing adhesion is 51.2% in *Clostridium difficile* contact precaution, and conformity to protocol is 17.5%. Wearing gloves impairs hand disinfection especially in situation where gloves are not part of the protocol (38.7%). Adhesion to mask wearing in airborne precaution is 90.7%.

Keywords: Video; Hand hygiene; Healthcare worker; Behavior; Healthcare practices; Isolation precautions

Introduction

Hand hygiene practice has been proven to be efficient to limit the spread of infectious diseases in hospital setting [1]. Measurement of hand hygiene compliance is an important component of infection control programs [2,3]. The World Health Organization (WHO) recommends regular monitoring to improve the hand hygiene compliance. Currently, most healthcare facilities measure hand hygiene compliance almost exclusively via direct human observation of healthcare workers [4,5]. While considered as the "gold standard" [6], direct observation is labor-intensive and susceptible to observer biases [6-8]. The observation bias has been investigates and proven to influence the behavior of the observed person [9]. Furthermore, the reliability of directly observed hand hygiene audits as a reflection of overall performance can be adversely affected by sporadic or inconsistent sampling [6]. Using such monitoring method, the compliance of hand hygiene is varying from 4-100% [4]. Despite many interventions, hand hygiene practices remain very poorly followed in most hospitals. One should investigate conditions during care that could explain this poor adhesion. Video recording is commonly used in sport coaching to analyze and improve practices [9,10]. Video recording has also been used in health care to explain the falls of elderly [11] and to allow corrective measures. To our knowledge only one study already use remote video analysis of hand hygiene in intensive care unit (ICU), with feedback to the health Care Workers (HCWs) showing a significant improvement [12,13]. We decided to use video recording to investigate the HCWs practices during time of care and identify conditions that would explain poor hand hygiene compliance and non-adhesion to isolation precaution protocols [14,15].

Method

We studied the hand hygiene practices all along the HCW pathway during time of care. The HCWs were identified according to their professional category, sex and educational level. We extracted from videotapes information regarding hand hygiene practice, its interference with meal tray delivery, housekeeping, the mask and gloves wearing. Repeated situations were characterized and classified for further statistical analysis. Furthermore, as hand hygiene depends upon patient's isolation procedure we notified when room was in *Clostridium difficile* isolation, airborne, or contact isolation procedures [16].

As for glove wearing we notified the wearing and the conformity to protocols. In standard, and airborne precaution situations, we defined that wearing gloves is conformed when gloves were put on within the room and removed before exit from the room. In *Clostridium difficile* isolation wearing gloves is conformed when gloves were worn before enter into the room and removed before exit from the room. Finally we studied the hand hygiene practices depending on the type of care. For doing this we define three care situations: Non-invasive care (medical examination, temperature, blood pressure, and treatment delivery), Invasive care (blood puncture, blood sampling, catheterization, blood transfusion) and nursing including bandage, urines and tools collection. The observation took place in an infectious diseases service of the University Hospital in Marseille France. All HCWs working

***Corresponding author:** Philippe Brouqui, Institut Hospitalo-Universitaire Méditerranée Infection, 13005 Marseille, France, Tel: +334 91 38 55 17; E-mail: philippe.brouqui@univ-amu.fr

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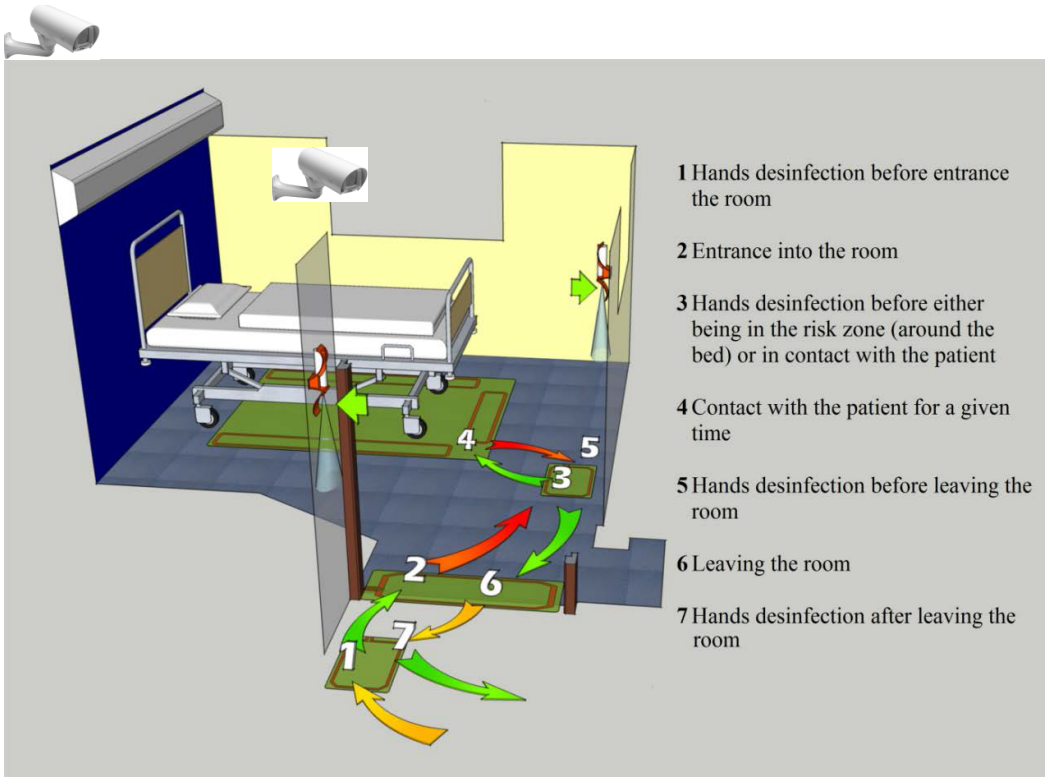

Figure 1: Schema of the experimental room with video camera and antennas from MédiHandTrace®.

there were asked to participate, including nurses, students, assistant nurses, housekeepers and physicians. A video camera was installed in one room of the ward, specially equipped with a continuous automated hand hygiene monitor MediHandTrace (r) [17] (Medihandtrace SAS BP 70351, 83077 Toulon cedex 9 France) as shown in Figure 1. The video camera was installed in such a way that only HCWs and not patient were recorded. The video camera was automatically started once a HCW enters into the room and stops five seconds after (s) he exits from the room as determined by MediHandTrace®. All video recording were detained on the MediHandTrace® server [17]. Videos were further analyzed by a nurse (SB) and a sociologist (PP).

When needed, variables were compared by using exact Fisher test or Chi². A significant different was established when p value < 0.05. In order to ensure anonymity of the data analyzed, a random number was attributed to each participant when captured in the database. Two experts did this analyze. The first was a nurse from the team care and the second was a sociologist. Only the experts knew the HCWs names and faces. In the videotape presented here, faces were hidden in order to preserve anonymity. In all case, an oral and written consent was obtained from the HCWs. We systematically asked agreement of the patient. If the patient refused (s) he was displaced to another bedroom. This ethic statement was declared to the French Commission on Individual Data Protection and Public Liberties (CNIL).

Results

In this study, 756 videos were captures from November 30th (2012) to February 13th (2013). 507 videos were analyzed and 249 rejected because the health care worker path was not completely recorded on the video. The 507 videotapes identified 1123 HCW paths. Of them 811 were analyzed, 312 HCW paths were rejected because there were no visible information about the use of the hydro alcoholic solution.

Use of hydro-alcoholic solution in the patient's room:	N (%)
At both entrance and exit	70 (8.6%)
Only at entrance	21 (2.6%)
Only at exit	72 (8.9%)
At entrance (missing data for exit)	14 (1.7%)
At exit (missing data for entrance)	52 (6.4%)
At least one time during the HCW path (either entrance or exit)	229 (28.2%)
Never	582 (71.8%)
Total	811

Table 1: Hand disinfection among HCWs in hospital setting (N=811 paths, France, 2013-2014).

Among 75 HCWs, asked to participate all accepted but 13 were further excluded from this analysis with the rejected videos (see above). Finally of 62 HCWs participate, 14 were nurses, 6 assistant nurses, 4 housekeepers, 28 medical students and 10 medical doctors.

Overall, of the 811 observed paths in the patient' room, HCWs had hand disinfection at least one time in 229 (28.2%) of path (Table 1). HCWs had hand disinfection both at entrance and exit of their path in 70/811 (8.6%) and at entrance only in 21/811 (2.6%) of path. Hand disinfection adhesion was significantly different between HCWs categories (p value < 0.0001). We observed that hand disinfection was the highest for medical doctors, then for medical students, then for nurses, then for housekeepers and finally for nurses assistant (Table 2). When the HCWs get into the bedroom with a meal tray, adhesion to hand disinfection is observed in 12/95 (12.6%) which is significantly lower than when the HCWs get in the room without meal tray 217/716 (30.3%) p=0.0003 (Table 2). This could be illustrated in many videos: typically, the assistant nurse entered into the room

	*p**	*Number of HCWs*	At least one time N=229 (28.2%)	Never N=582 (71.8%)	Total (N=811)
			N (% row)	N (% row)	N (% column)
HCW Categories	<0.0001				
nurse		14	107 (37.8%)	176 (62.2%)	283 (34.9%)
nurse assistant		6	6 (2.9%)	203 (97.1%)	209 (25.8%)
housekeepers		4	22 (15.8%)	117 (84.2%)	139 (17.1%)
medical students		28	72 (49.7%)	73 (50.3%)	145 (17.9%)
medical doctors		10	22 (62.9%)	13 (37.1%)	35 (4.3%)
Meal Tray Delivery	<0.0003				
yes		15	12 (12.6%)	83 (87.4%)	95 (11.7%)
no		61	217 (30.3%)	499 (69.7%)	716 (88.3%)
Patient into the Room	<0,0001				
yes		62	227 (30,7%)	513 (69,3%)	740 (91,2)
no		15	2 (2,8%)	69 (97,2%)	71 (8.8%)
Housekeeping	<0.0001				
yes, patient in the room		8	20(39.2%)	31(60.8%)	51 (6.3%)
no patient in the room		10	0(0.0%)	49(100.0%)	49 (6.0%)
no housekeeping		62	209	502	711
Type of the HCW path	<0.0001				
Surreptitious entry		27	4 (4.5%)	85 (95.5%)	89 (11.0%)
no contact		43	40 (32.0%)	85 (68.0%)	125 (15.4%)
Contact with environment		36	73 (21.7%)	263 (78.3%)	336 (41.4%)
contact with patient		42	112 (42.9%)	149 (57.1%)	261 (32.2%)
Type of Care	<0.000025				
non invasive		17	16 (25.0%)	48 (75.0%)	64 (7.9%)
invasive		13	38 (43.7%)	49 (56.3%)	87 (33.2%)
nursing		38	63 (56.8%)	48 (43.2%)	111 (42.4%)
not affected		58	112	437	549

**Chi test/ Exact Fisher test*

Table 2: Using of sanitizer

Hand Disinfection N=97					
	*p**	Before patient contact	After patient contact	Before + After patient contact	Total
Type Of Care	0.025				
non invasive		4 (7.7%)	31 (59.6%)	17 (32.7%)	52 (53.6%)
invasive		2 (6.7%)	9 (30.0%)	19 (63.3%)	30 (30.9%)
nursing		3 (20.0%)	8 (53.3%)	4 (26.7%)	15 (15.5%)
Total		9 (9.3%)	48 (49.5%)	40 (41.2%)	97 (100.0%)

**Exact Fisher test*

Table 3: Hand disinfection and type of care.

with the meal tray, she put it on the table and exits the room without having hand disinfected (Supplemental Digital Content Video N°1). In some paths (mainly for housekeeping: 49 of 71 or 69%) the patient can be out of the room. When the patient is in the room, the HCWs especially the housekeepers had hand disinfection significantly more frequently than when there is no patient ($p<0.0001$) (Table 2). When the HCW is in contact with the environment, hand disinfection is significantly lower than when there is no contact at all ($p=0.02$) (Table 2). Independently from the type of care, hand disinfection rate is always higher after than before contact with the patient (Table 3). When bedrooms were in isolation precaution for *Clostridium difficile*, 21 of 41 paths (51.2%) were made with gloves but the conformity of gloves wearing to protocol is respected in only 7/41 of paths (17.5%) (Table 4). In all situations, wearing gloves significantly impaired hand disinfection 77/316 (24.4%) versus 152/488 (31.1%) ($p= 0.037$) (Table 5). In situations in which gloves are not mandatory (standard, and airborne precaution situations), hand disinfection is significantly lower when gloves are worn 67/295 (22.7%) versus 150/468 (32%) ($p=0.0064$) (Table 5). This is illustrated, where an assistant nurse enters with gloves in a room without isolation precaution, she takes the urinal of the patient and goes to the bathroom. She brings the urinal back to the patient and then exits the room with gloves and unidentified material of care (Supplemental Digital Content Supplemental Digital Content Video N°2).

When bedrooms were in airborne isolation, the mask was appropriately worn in 353/389 (90.7%) (Table 6). This is illustrated, where a nurse enters without a mask into a room with airborne precaution. An assistant nurse gets into the room wearing a mask. She furtively gets out and reenters the room with another mask for the nurse (Supplemental Digital Content Video N°3) [Supplementary A-C].

Discussion

In our study, for the first time healthcare workers practices

Type of Isolation					
	*p**		C. *difficile* isolation N=41 (%)	Others or no isolation N=770 (%)	Total (N=811)
Wearing Gloves	0.11				
YES			21 (51.2%)	295 (38.7%)	316 (39.3%)
NO			20 (48.8%)	468 (61.3%)	488 (60.7%)
Missing data			0	7	7
Conformity For Wearing Gloves	0.37				
YES			7 (17.5%)	35 (12.4%)	42 (13.0%)
NO			33 (82.5%)	248 (87.6%)	281 (87.0%)
Missing data			1	19	20
Not affected			0	468	468
**Chi test*					

Table 4: Conformity for wearing gloves in *Clostridium difficile* isolation precaution.

Hand Disinfection				
	*p**	At least one time N=229	Never N=582	Total N=811
Wearing Gloves	0.037			
YES		77(24.4%)	239 (75.6%)	316 (39.3%)
NO		152 (31.1%)	336 (68.9%)	488 (60.7%)
Missing data		0	7	7
Wearing Gloves Only in no isolation	0.0064	At least one time N=217 (28.4%)	Never N=546 (71.6%)	Total N=763
YES		67 (22.7%)	228 (77.2%)	295 (38.7%)
NO		150 (32%)	318 (67.9%)	468 (61.3%)
Missing data		0	7	7
Wearing Gloves in C.D isolation		0	0	41
**Chi test*				

Table 5: Gloves wearing and hand disinfection.

Type of Isolation					
	*p**	Number of HCWS	Other isolations N=423 (%)	Airborne isolation N=388 (%)	Total (N=811)
Wearing Mask	<0.0001	n (% column)	n (% column) (% row)	n (% column) (% row)	
YES		42	36 (8.5%) (9.3%)	353 (91.0%) (90.7%)	389 (48.0%)
NO		53	387 (91.5%) (91.7%)	35 (9.0%) (8.3%)	422 (52.0%)
**Chi test*					

Table 6: Wearing mask and type of isolation.

were observed in routine care by video recording. Our results show that hand disinfection rate is very low and much lower than other published studies [4] but consistent with that of Armellino who reports 6.5% compliance at the beginning of their study [12,13]. Unlike observational studies using WHO protocol [1,6], our results and that of Armellino were much lesser influenced by the "Hawthorn effect" [7,12,18]. Blind analysis and comparison by two different observers likely attenuate a possible interpretation bias. Videotapes have been archived and can be further analyzed if needed which is one of the main advantages of video recording. It is important to notice that remote video recording is time consuming, and that these data should be interpreted with care as they reflect the situation in one care unit in a short duration of observation.

In our study, the hand hygiene adhesion is disturbed in two situations, namely gloves wearing and meal tray delivery. As reported in many studies gloves are worn in situation were not indicated and vice versa [19]. The hand disinfection compliance rate in our study as well as in other reported study was significantly reduced when gloves are worn [20]. Gloves wearing create confusion among HCWs. Non-sterile gloves are mostly used as a protection towards patients' body fluids during nursing by assistant nurses. They wear glove after room entry and hand disinfection prior to gloves wearing in not performed. Among HCW's explanation is the difficulty to wear gloves upon wet hands, and time waste. In *Clostridium difficile* isolation procedure, gloves must be worn before room entrance and removed into the room before exit [15]. The complexity and the diversity of protocols and the fact that these protocols dictated by infection control team may explain that they are poorly observed.

Hand hygiene is worst in situation where the meal tray is given to patients. In our experience 87% of HCWs that deliver the meal never use hand disinfection. In one recently published study in an emergency medical service hand sanitizing were observed in 19% of cases only before meal delivery [21-26]. This discrepancy may be due to the fact that hand hygiene outside the room was not evaluated in our study considering that only hand hygiene in the room at patient's bedside was appropriated. Caring the tray does not facilitate hand disinfection

taking into account the fact that time spent for delivery is short due to meal preservation conditions. However if hands are not disinfected before meal delivery it could be done just after, and before exit from the room.

Compliance with mask wearing is very high (90.7%). Airborne isolation is mainly linked to tuberculosis which appears as a specific contagious disease and one may suggest that this difference in behaviors may be related to risk perception of acquiring the disease and transmitting to close contact. This risk appears as most visible that hand transmit nosocomial infection. In infectious disease ward very few if no patient acquire infection in the time of care (mean length of stay < 8 days), which may contribute to the thinking that in infectious disease ward, HCWs are, not involved in transmission. Our study has some limitations. The observations were done in only one room. Video recording was performed only within the room making hidden all events outside the room. Although very efficient [12,13], we do not believe that remote video analysis is a tool for improving and maintaining hand hygiene compliance as it poses numerous privacy questions, is time consuming and very expensive. However remote video analysis is a performing tool in research to study health care workers behavior and understanding issues that might explain poor compliance.

In conclusion, as used in sport, video recording is a tool that can be useful for studding performance in health care practices allowing to identified yet unidentified situations. The lack of adhesion to hand hygiene is multifaceted. The analysis of videotapes allows observing the real life with minor bias. While wearing gloves disturb the sequence of care gestures, hand hygiene before meal tray delivery is questionable. More simple hand hygiene protocols including gloves wearing, focusing on high-risk transmission practices (ex: during nursing and invasive care) and adapted to health care workers behavior would improve the compliance of hand hygiene and adhesion to isolation protocols.

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PUBLICATION COMPLEMENTAIRES

Article N°6: New Approaches to Prevent Healthcare-Associated Infection

Philippe Brouqui, Sophia Boudjema, Alberto Soto Aladro, Eric Chabrière, **Olga Florea**, Hoa Nguyen and Jean Charles Dufour

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SUPPLEMENT ARTICLE

New Approaches to Prevent Healthcare-Associated Infection

Philippe Brouqui,[1,2] Sophia Boudjema,[1,2] Alberto Soto Aladro,[1,2] Eric Chabrière,[1,2] Olga Florea,[1,2] Hoa Nguyen,[3] and Jean Charles Dufour[4,5]

[1]Institut Hospitalo-Universitaire Méditerranée Infection, AP-HM, Marseille, France; [2]Aix Marseille Univ, URMITE, UM63, CNRS 7278, IRD 198, INSERM 1095, [3]École nationale supérieure des mines d'Alès, and [4]Aix Marseille Univ, INSERM, IRD, SESSTIM UMR912, Marseille, France; and [5]Assistance Publique Hôpitaux de Marseille, BIOSTIC Service Biostatistique et Technologies de l'Information et de la Communication, Hôpital de la Timone, Marseille, France

Healthcare-associated infection (HCAI) in hospitals mainly results from unsolved but well-identified causes such as hand hygiene, overuse of catheters, and to a lesser extent, the airborne transmission of infectious agents caused by the misuse of respiratory precautions. The aims of the Institut Hospitalo-Universitaire Méditerranée Infection are to develop new approaches to fight HCAIs. Among them, new technologies that allow for the traceability of care and good practices reminders have been developed concomitantly to an anthropological approach, facilitating acceptability by healthcare workers. While the automated continuous monitoring system is validated and commercially available, some other technologies are still under clinical evaluation or in the early development phase. Quorum sensing–based biotechnologies are developed with the aims to fight against wound colonization.

Keywords. heath care associated infection; technological devices; infection control; anthropological approaches; biotechnology.

Healthcare-associated infection (HCAI) affects approximately 5 million people each year in Europe with an estimated cost of €13–€24 billion, and an attributable mortality varying from 50 000 to 135 000 cases [1]. In the United States, the annual rate of HCAI was estimated at 1.7 million cases, with 99 000 deaths and an economic impact of approximately US$6.5 billion. The estimated prevalence rate varies across the globe, from 5%–10% of hospital-admitted persons to 20%–30% of patients admitted in intensive care [2]. HCAI infection is the largest epidemic of infectious disease that has ever happened on Earth, with an estimated number of deaths of at least 250 000 cases per year just in the United States and Europe, with a cost of €30 billion yearly. Aiming at a reduction of 10% of total HCAI, the saved lives and money would be estimated at 2500 and €3 billion per year, respectively.

Due to the fact that most HCAIs are the results of microorganism transmission by hand, hand disinfection is regarded as key to fight against this epidemic. Cleansing hands with alcohol-based hand rub is a simple and undemanding procedure that requires only a few seconds and has been proven to be highly efficient [3]. Even if the relative risk level of different care activities and how to best define key moments for hand hygiene action are still debated among infection control experts, the "5 moments for hand hygiene" are generally admitted as key moments for efficient hand hygiene [4]. However, these 5 moments can be classified into 2 simple key actions: hand disinfection before contact with the patient and hand disinfection before leaving the contaminated healthcare zone (patient's bedroom). The observed adherence rates among healthcare workers (HCWs) have been regarded by public health authorities as unacceptably poor. There is no standard for measuring adherence to hand hygiene practices; however, directly observing adherence to hand hygiene recommendations is the method used in the majority of studies [2]. Direct observational surveys suffer from several limitations; they are time-consuming and costly, they do not allow for continuous monitoring, and they only provide information on a small sample of all hand hygiene opportunities. More importantly, staff members change their behavior when they know that they are being observed; this has been called the "Hawthorne effect" [5].

Bloodstream infection (BSI) is a major cause of morbidity and mortality throughout the world. The estimated number of hospital-acquired BSIs in 2002 in the United States was 215 000 cases, with a calculated incidence of 2.2 cases per 100 admissions (0.6 in all hospitalized patients and 9.7/100 admissions in the intensive care unit) [6]. Even if many studies have been conducted to prevent nosocomial BSI, some with success [7], in a recent matched case-control study of 830 hospital-acquired BSIs by the elderly, the mortality attributable to the hospital-acquired BSI was 2 times that of the controls, the added length of stay was of 10 days, and the total added cost was US$43 208 per patient [8]. Although peripheral venous catheters (PVCs) are the most frequently used invasive devices in hospitals with an estimated incidence varying from 30% to 80% of hospitalized patients, problems caused by PVCs are largely underevaluated [9]. Studies reporting infectious complications of such catheters

Correspondence: P. Brouqui, IHU Méditerranée Infection, 19-21 bd Jean Moulin, 13005 Marseille, France (Philippe.brouqui@univ-amu.fr).

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are rare. It has been estimated recently that *Staphylococcus aureus*–associated PVC bacteremia would occur in up to 10 000 patients yearly in the United States [10]. The rate of unnecessary PVC use reaches 50% in the literature [11] and, in our own experience, 80% of patients admitted though the emergency department [12], explaining why fighting PVC has become a major aim for the Institut Hospitalo-Universitaire (IHU).

Finally, although the impact in term of incidence, mortality, and cost is much lower, hospital-acquired respiratory infections such as influenza, syncytial respiratory virus, measles, tuberculosis, Legionnaire's disease, herpes zoster virus, and others require paying a particular attention in taking care of these contagious patients. Highly contagious patients such as those with viral hemorrhagic fever or with severe acute respiratory syndrome or Middle East respiratory syndrome coronaviruses need the expertise of a skilled team in infection control [13].

NEW APPROACHES TO PREVENT CONTAGIOUS DISEASES AT THE INSTITUT HOSPITALO-UNIVERSITAIRE

Innovative Technological Approaches

Electronic hand hygiene monitoring systems have emerged not only to record compliance but also to promote it. These systems are designed to ensure that HCWs perform hand hygiene before approaching the patient's bedside and issue an alert to do so. They can use sensors that detect alcohol vapors [14] or radiofrequency identification to determine when hand hygiene has occurred [15]. Among systems that are more widespread, including for a use in medical equipment, there are Wi-Fi (wireless system based on Institute of Electrical and Electronics Engineers [IEEE] 802.11 standards) and Zigbee (wireless communication protocols based on IEEE 802.15.3 standards) [16]. Both receivers are low-cost, are easy to maintain, and can be portable. The disadvantage of Zigbee and Wi-Fi is that an accurate location may require multiple beacons in an area, or combination with another technology; some systems may record 2 HCWs with hand hygiene even if the HCWs are very close in proximity [15]. The remote video monitoring of hand hygiene with real-time feedback to HCWs was responsible for a significant increase in hand hygiene compliance [17]. The main disadvantage of the video is that it is linked to human interpretation, time-consuming, and not in real time for the feedback and analysis. The main gap with these technologies is that they are currently unable to define the exposure to transmission (contact with the patient or with contaminated fomites); even if some technology claims that they can do it, few have been evaluated for accuracy, sensitivity, and specificity [18, 19].

The IHU Méditerranée Infection has favored the emergence of technical innovation by making it possible to share scientific ideas with industrial development. The technology developed by our consortium and called here MediHandTrace (French patent register 12/60453) was born from an informal discussion between a small research and development (R&D) office (MicroBE), a bedside hand hygiene sanitizer distributor (Hygienic System), and a counseling office (EphygieHand). Our technology is based on radio-frequency identification (RFID). In brief, the system was based on the "iCode RFID 15693" tag technology using the frequency band of 13.56 MHz. Originally, each bedroom was equipped with 4 floor-level antennas used to read tags inserted in the shoes of each HCW (Figure 1A). One antenna was located just outside the room's door under the alcohol dispenser, the second antenna was located at the door entrance, the third was within the room under another alcohol dispenser, and the last antenna was located around the bed and defined a secure zone (ie, contaminated healthcare zone, the zone for which alcohol disinfection should have been performed before entering). Sensors were placed on both alcohol dispensers, measuring the use of hydroalcoholic solution inside and outside the room by indicating the number of sprays and the volume dispensed. One reader coordinates the antennas to read the HCWs' shoe-inserted tags and the dispenser's sensors, and transfers the information to the main server via an Ethernet connection. The intelligence of the system lies in the server, which manages, interprets, and provides results in real time. A new mobile system has just been released with only one antenna and one hydroalcoholic solution dispenser at the bedside. Information on entrance and exit of the HCW is given to the system by a signal transmitted to the antenna by one tag located under the door (Figure 1B). All of our innovations are protected either by patent or by copyright. MediHandTrace has been evaluated against video recording with a sensitivity of 95.65 %, specificity of 100%, and accuracy of 99.02% [20]. The consortium created ex-nihilo a startup named MediHandTrace SAS (125 000 €), which engaged in new R&D. The product is now commercially available in any place in the world (http://www.medihandtrace.com/en/home-1.html). In parallel with R&D, our research group investigated the impact of the developed technique. In a recently submitted article, we reported that we were able to record HCW paths and hand hygiene opportunities 247 and their appropriate hand hygiene for up to 5 months. We showed after a multilevel linear regression adjustment that HCWs initially did not disinfect their hands before contact with the patient in 77.4% of hand hygiene opportunities, indicating a hand hygiene adherence rate of 22.6%, with 6% only performing hand hygiene just before contact (Figure 1A, sequence 3–4) [21]. Interestingly, this was associated with a use of 7.48-fold the European recommended hand rub solution volume, indicating that the level of hand rub solution of 21 mL/day/patient for medicine wards currently recommended was too low [22]. This study raised an important point: The fact that hand hygiene is HCW dependent and that such technology records a very large number of events indicates that the number of hand hygiene opportunities (related to workflow) of one particular HCW with his or her own hand hygiene practices overweights this HCW's features, needing adjustment (multilevel

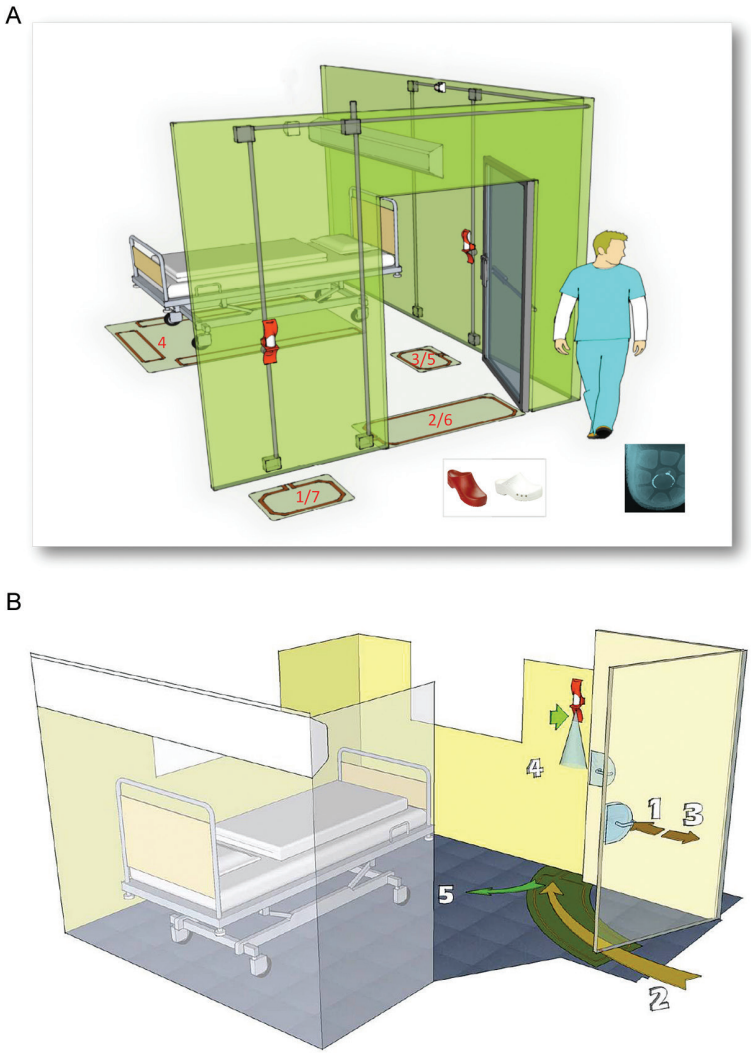

Figure 1. *A,* MediHandTrace 1.0 Hand Hygiene continuous monitoring system. Microchips are introduced in the healthcare worker's (HCW) shoes (inset). The signal is transmitted to the database Meditrace: S1 when the HCW is on the first antenna; S2 when he is on the door antenna; S3 when he is on the inside dispenser antenna; S4 when he is in contact with the bed antenna; S5 when he returns to the inside dispenser antenna after S4; S6 when he is in contact with the door antenna after S4, S3, or S5; and S7 when he is in contact with the outside antenna. A signal is sent to the database when alcohol solution is taken either outside or inside the dispenser. Example: the sequence "1, 2, 3, 4, 5, 6, 7" with alcohol taken at 3 and 5 is a perfect path; the sequence "1, 2, 4, 5, 6, 7" with alcohol taken at 1 and 7 is acceptable; the sequence "1, 2, 4 …" is an inacceptable path. *B,* In this new version of MediHandTrace, the tag 1 is located under the door and targets the signal when the door opens over the unique antenna. Here, signal S1 indicates the entry; S2 identifies the HCW; S3 indicates that the door was closed; S4 indicates that the HCW takes alcohol hand rub; S5 indicates the HCW leaves the antenna. Note that here the "care zone" has been enlarged to the whole bedroom, whereas in the first version the care zone was restricted to the bed zone.

analysis) to attenuate this overexpression [23]. Among others, the shorter the duration of the path, the worse the bedside hand hygiene, indicating that the organization of care is a key factor to improving hand hygiene [21]. Since that time, the system continuously recorded HCW hand hygiene opportunities. With the use of MediHandTrace, in the aims to improve hand hygiene, we have monitored the HCW hand hygiene practice changes after sending small text message feedbacks. The participants in our study received one of 2 types of text message every Monday morning. The first type is a felicitation message: "From date X to date Y, you have improved your hand hygiene. Congratulations, and keep up the good work." The second type is an encouragement message: "From date X to Y, your hand hygiene did not improve, and we encourage you to be more vigilant." We have recorded 15 723 paths all along our study (10 months) done by 18 HCWs. After a multilevel logistic regression model to integrate the individual effect on compliance to hand hygiene, HCWs receiving text messages improved their hand hygiene by almost two-fold (odds ratio, 1.68 [95% confidence interval, 1.45–1.79]; $P = .001$) [24]. Studies are ongoing to evaluate the impact of reorganization of care (nursing kit) on hand hygiene adherence.

Video Monitoring of Routine Healthcare

Despite the fact that video monitoring is time consuming and does not give real-time feedback, it was proven useful in enhancing hand hygiene [17]. Video recording and feedback are commonly used in sport coaching and improving practices, and video recording has been associated with MediHandTrace to evaluate HCW behavior in routine care, highlighting the complexity of hand disinfection and glove wearing [25, 26].

Peripheral Venous Catheter Traceability

Excepted care bundle interventions, very few studies have been performed to reduce unnecessary insertion or as soon as possible (ASAP) ablation of PVC, most studies focusing on central venous catheters [27]. We innovated with 2 different technologies in an attempt to stop exceeding insertion and allowing an ASAP removal of unnecessary PVCs. The patient smart reader (PSR) is a bar code personal digital assistant capable of scanning the catheter, the nurse, and the patient's bar code identification, allowing the optimization of PVC traceability. It also can inform, for every 8-hour shift, the nurse in charge to obtain the medical renewal of the catheter prescription and, if not, to remove the catheter. PSR also informed and traced each 8-hour shift for catheter maintenance. When compared to other standardized process of traceability, the PSR allowed for an increase from 58.3% to 100% ($P < .05$) in the traceability of catheter insertion and removal (O. Florea et al, unpublished data). Further studies are ongoing to evaluate the impact on PVC line infection. The second innovation is an intelligent PVC (KTtrace), which, when inserted into the patient's arm, continuously informs the HCW of its presence, and asks the HCW to regularly evaluate its need for an ASAP removal. This process is patented and under ongoing clinical evaluation.

Anthropological Approaches

New technologies introduced to monitor hand hygiene have been a matter of debate among HCWs. These technologies are better accepted by HCWs in leadership positions than among others. Among the questions raised by HCWs is the accuracy level of the data produced by systems to monitor hand hygiene and the inability of the technology to assess the situational context of hand hygiene opportunities, as well as the punitive use of data produced [28]. Our project was accompanied by human and social science evaluation. Scientific research in our infectious disease ward was presented by "reformers" (researchers) as a mandatory way to explore cause and consequence and improve the knowledge on HCAI to further adapt the intervention and reduce risk of HCAIs. This means legitimizing the introduction of new technologies and neutralizing the fears of HCWs. However, the HCWs' opinion is more nuanced; if they value scientific research in its goal to reduce HCAIs, they worry that these new technologies will not be without consequences for themselves and their profession. (C. Tarantini, manuscript in preparation).

Communication to Healthcare Workers

While signs are commonly used to remind physicians and nurses to perform hand hygiene, recent randomly assigned studies showed that signs did not significantly improve hand hygiene compared to baseline signs [29, 30]. It is not clear if this is because signs do not work or because current signs are not optimally designed. It has been shown that various evidence-based components are essential for the design of efficient signs, including gain-framed messages, alerting signal words, appeal to personal responsibility, appeal to patient consequences, a specific activity required from the reader, attention-getting features, and appropriate design features such as color and letter size. We are currently investigating this question with our own homemade signs.

Biotechnological Application of Quorum Quenching Enzymes

Quorum quenching (QQ) is a strategy using enzymes issued from quorum-sensing bacteria to fight biofilm formation and virulence factor secretion. The IHU has recently invested in the use of quorum-sensing bacteria by the creation of the Gene & GreenTK company. These approaches are appealing because they do not directly challenge bacterial survival and, consequently, selection pressure may be low, yielding a lower occurrence of resistance. QQ enzymes are particularly promising because they act extracellularly to degrade autoinducers and can be used in catalytic quantities. A recent review draws an overview of QQ enzyme–related applications, in particular, topical and dressing perspectives for treatment or decolonization of infected/colonized wounds [31].

CONCLUSIONS

Preventing transmission when caring for contagious patients is a complete approach, including the use of dedicated circuits, single room isolation, and rapid diagnostic tests with early and adapted treatment; enhancing hand disinfection and respiratory protection; avoiding unnecessary catheter use; improving the traceability of care; and reducing colonization by multidrug-resistant, gram-negative bacteria. New technologies or biotechnologies are likely to be of great help in such a challenge. HCWs should be enlisted to make these changes a success. These are the aims of the IHU.

Notes

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Communications congrès N° 1:

Patient Smart Reader®: Evaluation of a traceability system for peripheral venous catheters and urinary catheters.

Florea Olga: 2nd year of thesis specialty : Human pathologies
IHU Mediterranean 19-21 Bd Jean Moulin, 13005 Marseille
Director of thesis Pr P. Brouqui and Dr. Sophia Boudjema

Communiqué à congrès DOC2AMU INTERDISCIPLINARY DOCTORAL DAY - MARSEILLE OCTOBRE 2017

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Introduction

Peripheral venous catheter(PVC) and urinal catheter(UC) infections are responsible for many acquired infections in hospitals with 10 000 deaths/year. The fight against the unjustified insertion of the catheter is possible with a good traceability. The significant improvement of the catheter traceability's among hospitalized patients have been showed with a new informatics tool named Patient Smart Reader (PSR) which is compared to the classical system of traceability. The aim of our study is to evaluate the traceability of catheters with this new system compared with a gold standard.

Materials

Each room was equipped with the code bar scanner PSR. The information transfers through the wifi connection to the server. The intelligence of the system lies in the server, which manages and provides results and alarms in real time with *Nurse's office back screen*.

Methods

A prospective study evaluating the diagnostic value of a test was implemented by evaluating the sensitivity and specificity of this test. All patients who came in our unit were included in our study. The necessity of peripheral venous catheters and urinary catheters was definite by senior doctor. Criterion of judgment was the number of catheters per day per patient and daily observation in real time was established as the gold standard (GS).

Fig 1. The Patient Smart Reader.

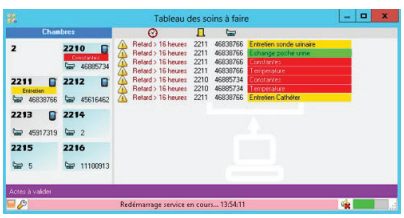
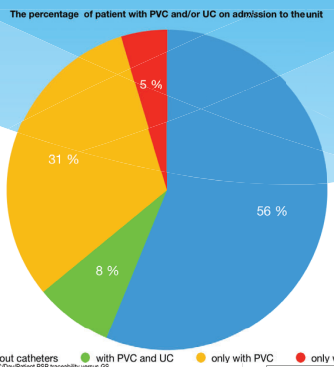
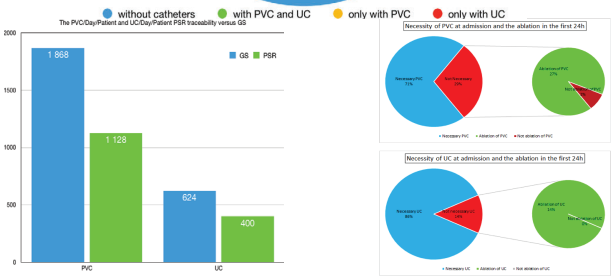


Fig 2. Nurse's office back screen

Results





PVC	PSR +	PSR -	
GS +	1195	1364	2559
GS -	121	1996	2117
	1316	3360	4676

ACCURACY	68,2 %
SENSITIVITY	90,8 %
SPECIFICITY	59,4 %
TRUE POSITIVE RATE	90,8 %
FALSE POSITIVE RATE	40,6 %

UC	PSR +	PSR -	
GS +	278	716	994
GS -	27	3655	3682
	305	4371	4676

ACCURACY	84,1 %
SENSITIVITY	91,1 %
SPECIFICITY	83,6 %
TRUE POSITIVE RATE	91,1 %
FALSE POSITIVE RATE	16,4 %

Accuracy, sensitivity and specificity of the Patient Smart Reader (PSR) traceability compared to real observation established as the gold standard (GS) of Peripheral Venous and Urinary catheters/day/patient

Conclusion

With a specificity about 60% for the traceability of catheters with PSR, we establish a protocol to evaluate this traceability system. We are going to use it to fight against unjustified insertion of catheters. To improve the specificity for traceability with PSR at 85%, we need to elaborate and implemented a specific individual engaging training for catheters traceability.

Communications congrès N° 2:

Comportement et Communication Engageante : Améliorer l'Observance à la Traçabilité

Florea Olga*, Albertini Thibaut*, Gonin Jérémy, Gaudart Jean, Boudjema Sophia, Richer Isabelle, Pascual-Espuny Céline, Durampart Michel, Brouqui Philippe

* Co-First/Equal authorship

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NANTES OCTOBRE 2021

Comportement et Communication Engageante : Améliorer l'Observance à la Traçabilité

Florea Olga*, Albertini Thibaut*, Gonin Jérémy, Gaudart Jean, Boudjema Sophia, Richer Isabelle, Pascual-Espuny Céline, Durampart Michel, Brouqui Philippe
* Co-First/Equal authorship

Introduction/Objectifs

Phlébites, hématomes et infections sont les évènements indésirables (EI) les plus courants liés aux cathéters des voies veineuses périphériques (VVP). Un monitoring régulier et conforme associé à un remplacement ou des retraits réguliers restent actuellement les seuls moyens efficaces pour réduire les EI. Alors que des outils facilitant la traçabilité des soins s'installent dans les services, leur utilisation au quotidien peine à s'imposer.
Notre travail a porté sur l'amélioration de l'utilisation de ces outils de traçabilité par des mesures et interventions sociales au sein d'un service dans lequel un outil de traçabilité, le *Patient Smart Reader* (PSR), a été installé au chevet des patients. Pour cela, nous avons créer une intervention basée sur le paradigme de la communication engageante, qui a pour but d'amener les individus récepteurs à échanger autour de leurs savoirs et problématiques, et de les amener à réaliser des actes particuliers, appelés « actes préparatoires engageants ».

Patient Smart Reader : PDA lecteur de code barre assistant la traçabilité des soins. En pratique, lorsque le soignant réalise un acte, il utilise cet outil pour scanner un code barre correspondant à l'acte qu'il vient de réaliser. La table des codes barre est affichée à côté de tous les points d'implantation de l'outil.

Matériel et méthode

Communication Engageante

La communication engageante est une méthode qui permet de créer des liens entre les savoirs et les actions individuels. La prise de conscience de la non-conformité entre savoirs et actions induit une dissonance cognitive qui va pousser le sujet à agir pour réduire cette dissonance.

En parallèle des données issues du PSR, nous avons consigné l'ensemble des actes réalisé sur les patients. Ces données ont été corrélés pour obtenir un pourcentage de conformité par soignant.

Intervention Engageante

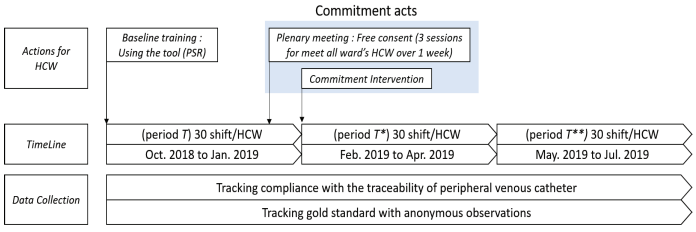
Nous avons procédé à une remise à niveau des connaissances relative à l'utilisation de l'outil pour tous les sujets. Chacun à ensuite été invité à participer, sur la base du volontariat, à une intervention d'une heure selon des créneaux décidés par eux.

L'intervention s'est déroulé en trois temps animé par « le formateur » : une discussion autour des raisons qui motivent la traçabilité des soins ; une discussion autour des problématiques rencontrées et des solutions individuelles trouvées pour l'utilisation de l'outil ; une sérié « d'actes préparatoires engageants » à faire réaliser aux sujets.

Les actes réalisés par les sujets :
- Synthèse et récapitulatif individuel des discussions sur bulletin anonyme
- Hiérarchisation du risque relatif aux manipulations des cathéters
- Étiquetage positif des soignants par le formateur
- Proposition de signature d'un document récapitulant les points énoncé sur les bulletin,
- Distribution de badge regroupant les 3 niveaux d'identification de l'action

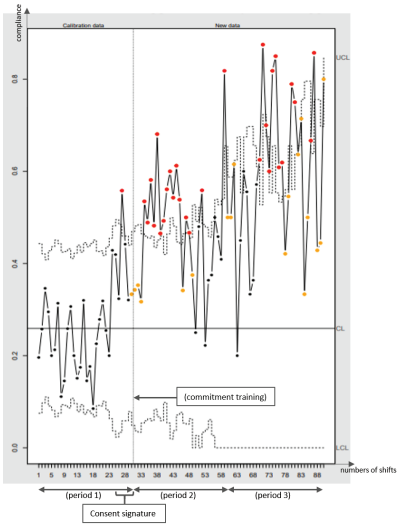
Afin d'assurer une reproductibilité de l'intervention, nous avons formé un formateur de notre institution à intervenir selon ce protocole.

Les données ont été observées selon trois périodes et un indicateur (I_1) :
- Période T : 30 vacations (par soignant) avant l'intervention
- Période T* : 30 vacations (par soignant) directement après l'intervention
- Période T** : 30 vacations (par soignant) après la période T* pour contrôler le maintien des effets dans le temps



Résultats

Les infirmiers « récepteurs » de cette intervention, ont observé une amélioration significative de l'observance à l'utilisation de l'outil pour la surveillance des cathéters au fil du temps (shift après shift), allant de 27,6 % d'observance avant « l'intervention engageante » (IC = [25,3 ; 30,0]) à 47,4% après « l'intervention engageante » (IC = [45,0 ; 49,9]).
L'intervention réalisée a augmenté de 2,42 (odds ratio) les chances d'effectuer un suivi des cathéters par l'outil PSR (IC = [1,88 ; 3,11]).



À la suite d'entretiens réalisé avec les sujets, il ressort que la mobilisation des savoirs experts des opérateurs de soins est plus appréciée que les méthodes de formation traditionnellement employées.
De plus les infirmiers questionnés étaient satisfait d'avoir eu un moment formel pour échanger entre collègues sur les problématiques rencontrées avec le PSR au quotidien ainsi que sur les solutions trouvées.

Aucun des personnels questionnés n'a eu la sensation de faire un effort particulier pour utiliser l'outil de manière plus régulière.

Variables	Odds Ratio	Confidence Interval	p-Value
(intercept)	0.15	[0.08-0.27]	p < 0.001
T (Period 1)	1.03	[1.01-1.04]	p < 0.001
$I_1(commitment\ training\ indicator)$	4.12	[2.96-5.73]	p < 0.001
T* (Period 2)	0.99	[0.97-1.00]	p = 0.044
T** (Period 3)	0.99	[0.97-1.01]	p = 0.312

Discussion/Conclusion

L'intervention engageante semble avoir amené un changement significatif dans les pratiques quotidiennes liée à la traçabilité des actes relatifs aux cathéters VVP.
Les résultats de notre étude sont à mettre en perspective avec les résultats d'autres études ayant utilisé des concepts et théories mobilisant la communication interpersonnelle comme facteur de changement. Nous pouvons ainsi citer les cadres de la déviance positive, de la théorie des nudges, ainsi que les méthodes de feedback de performance.

CONCLUSION ET PERSPECTIVES

Ses travaux ont été réalisés en utilisant des approches innovantes multidisciplinaires et technologiques, dans le but de lutter contre les maladies infectieuses en améliorant l'efficience, l'efficacité et la performance des soins hospitaliers. Pour améliorer l'efficience des soins infirmiers, nous avons validé deux technologies innovantes en combinaison qui montrent une aide dans l'amélioration de la traçabilité des soins et le lavage des mains pendant des gestes à risque.

Pour optimiser la pratique des soins infirmiers il existe un dispositif d'enregistrement des informations au lit du patient utilisant des code-barres (PSR®). L'étude a montré une amélioration importante et significative de la traçabilité avec le PSR® en temps réel en comparaison avec d'autres systèmes classiques pour les soins prescrit par les médecins ou nécessitant une traçabilité systématique.

Toutefois, les taux d'utilisation du PSR® sont insatisfaisants si nous comparons à l'observation réelle de présences des cathéters. Dans nos travaux, nous avons montré que la mise en place d'un protocole utilisant la communication engageante permet d'améliorer les performances de ce dispositif. Ce nouveau protocole nous offre une méthode efficace pour modifier les comportements des infirmières en matière de sécurité des soins. Les facteurs déterminants de l'engagement peuvent être des indicateurs permettant de définir les futures stratégies de communication et de formation dans les centres de soins pour l'ensemble du personnel soignant.

Tout au long de mes années de travail, grâce à MediHandTrace ® et PSR ®, nous avons obtenu des données massives de la compliance à l'hygiène des mains et de la traçabilité des soins. Une compliance faible d'hygiène des mains pendant des soins à risque a été constaté. Dans nos études précédentes [18,19], nous avons conclu que l'hygiène des mains du personnel soignant était dépendante de chaque individu. Des recherches plus approfondies sont nécessaires pour expliquer la causalité entre les comportements répétitifs et les attitudes implicites vis-à-vis de l'hygiène des mains.

En ce qui concerne la surveillance de la compliance à l'hygiène des mains, il pourrait être intéressant d'analyser la compliance individuelle sur le long terme de chaque personnel soignant pour prendre en compte les facteurs individuels. En effet, la recherche de l'amélioration individuelle des soignants à long terme reste un défi majeur en raison des forts taux de roulement (ou taux de rotation de l'emploi). De futures recherches devraient se consacrer aux facteurs individuels afin de mieux cibler la communication. Aujourd'hui, la technologie et notamment l'utilisation de données massives nous permettant d'avoir une vision globale mais parfois les réponses sont liées à des facteurs individuels et nécessitent une approche à l'échelle humaine.

Cette thèse renforce l'importance des démarches multidisciplinaires innovantes dans la lutte contre les maladies infectieuses. Le développement et l'utilisation d'outils technologiques tel que MediHandTrace ® et PSR ® permettent d'explorer les comportements des soignants en évitant les bais d'observations. On voit les limites de ces technologies et de nouvelles approches comme la vidéo dématérialisée, pourrait apporter une réponse à la surveillance continue de la qualité des soins en situation complexe.

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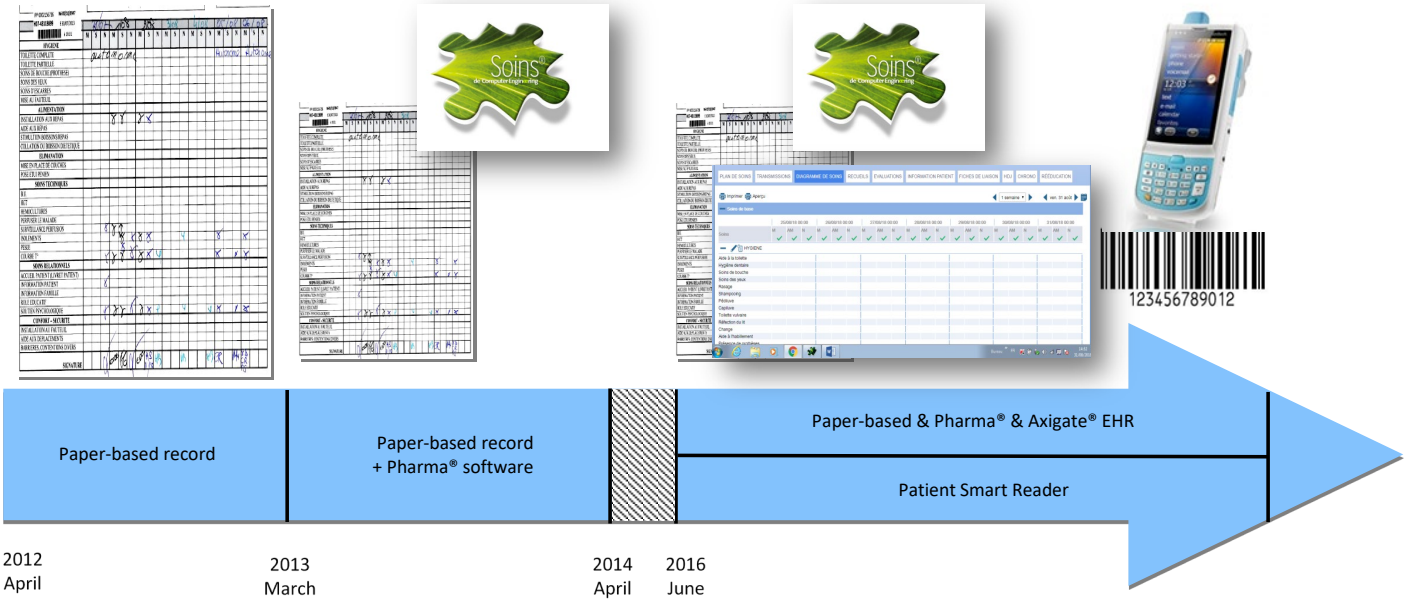
ANNEXES

Annexes 1. Evolution traçabilité IHU Marseille

Figure 1: Evolution in time of nursing records from paper-based records to PSR at IHU of Marseille



Annexes 2. Présentation du Patient Smart Reader (PSR)

Le PSR est un PDA (Personal Digital Assistant) doté d'un applicatif propriétaire. Le PDA utilisé est un appareil de marque Unitech spécifiquement destiné à une utilisation en milieu médical dont la référence est pa690mca.

Le PDA avec l'application Micro BE

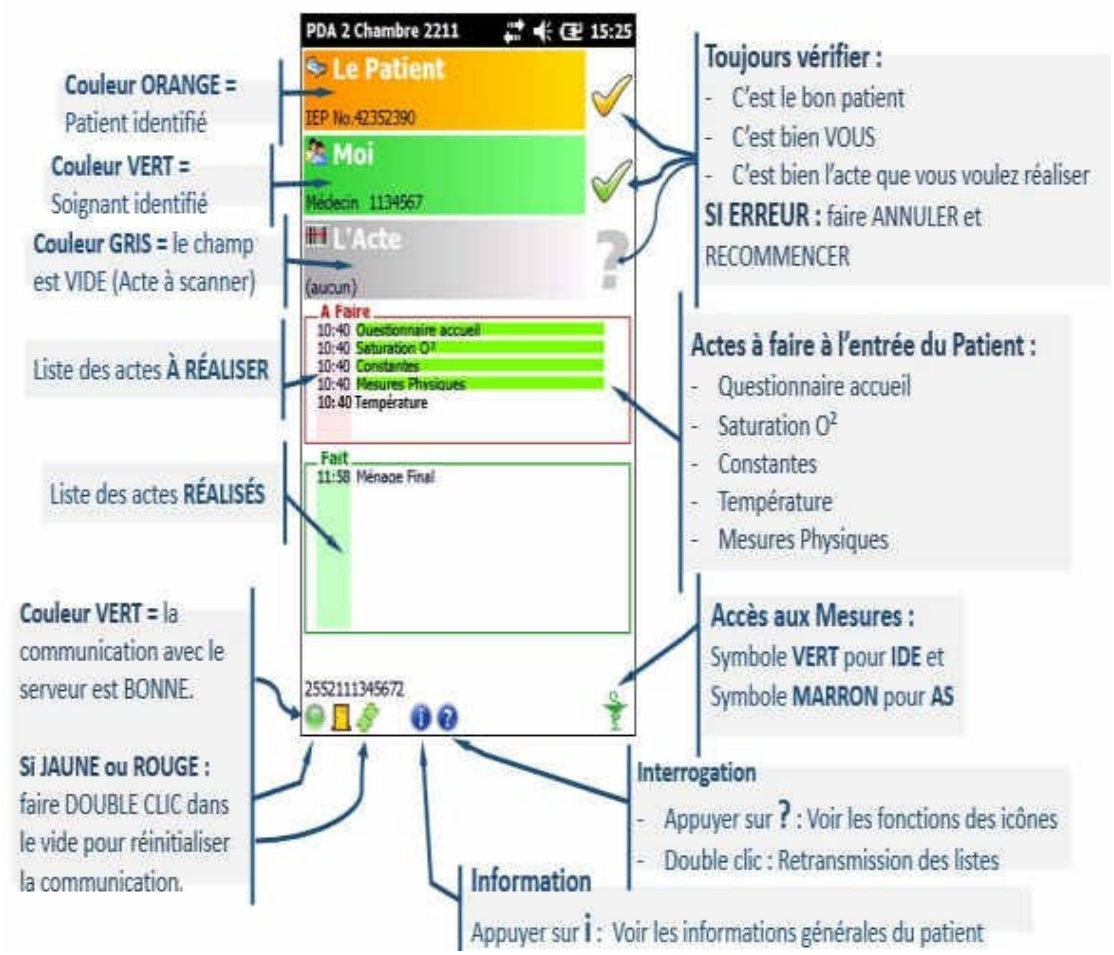
A scanner :

1 – Le patient

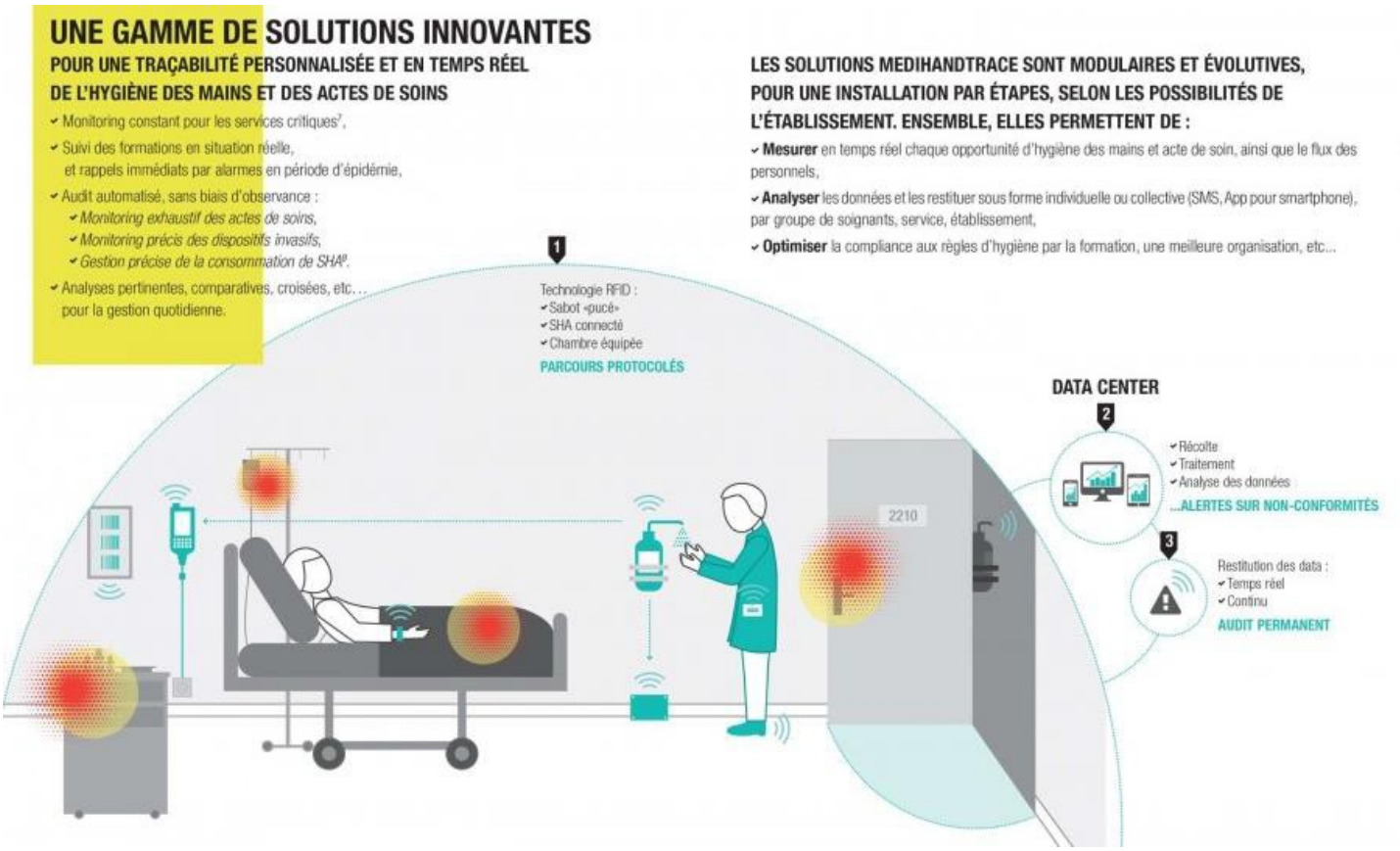
2 – Le soignant

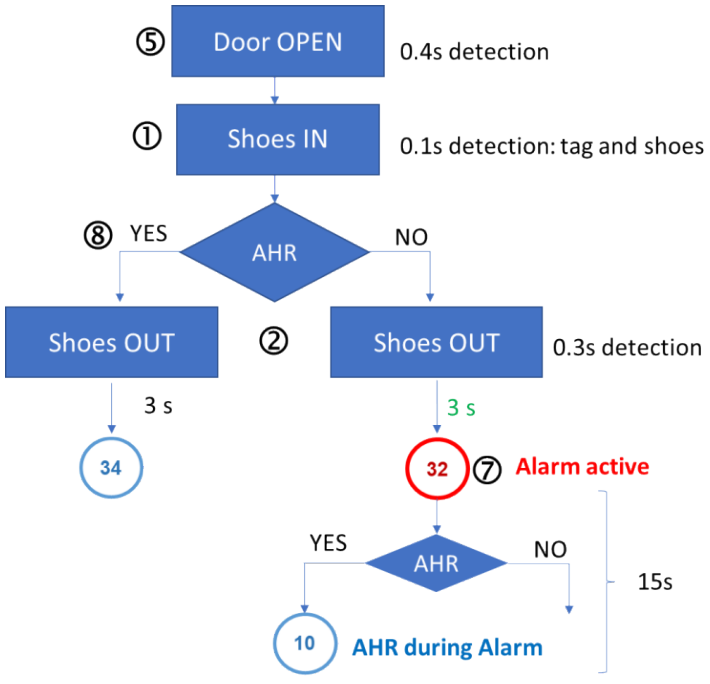
3 – L'acte

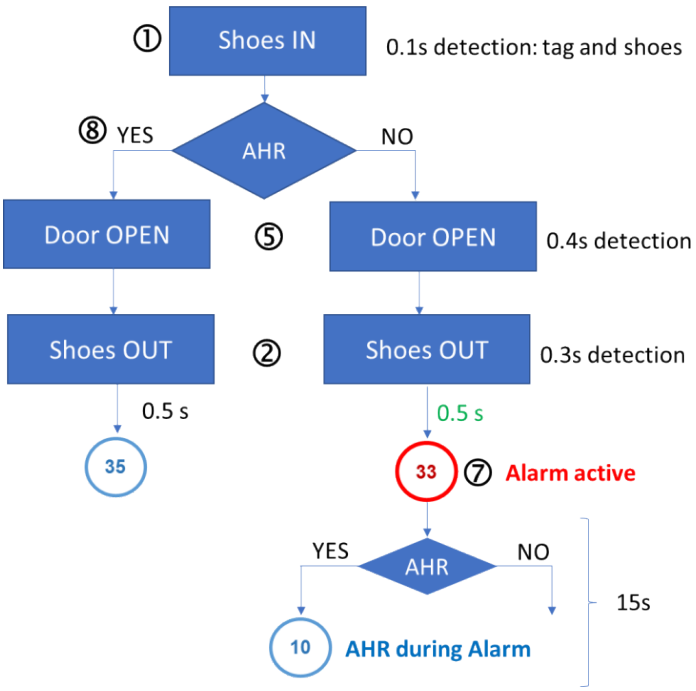
Details application



Annexes 3. Algorithme du système MediHandTrace





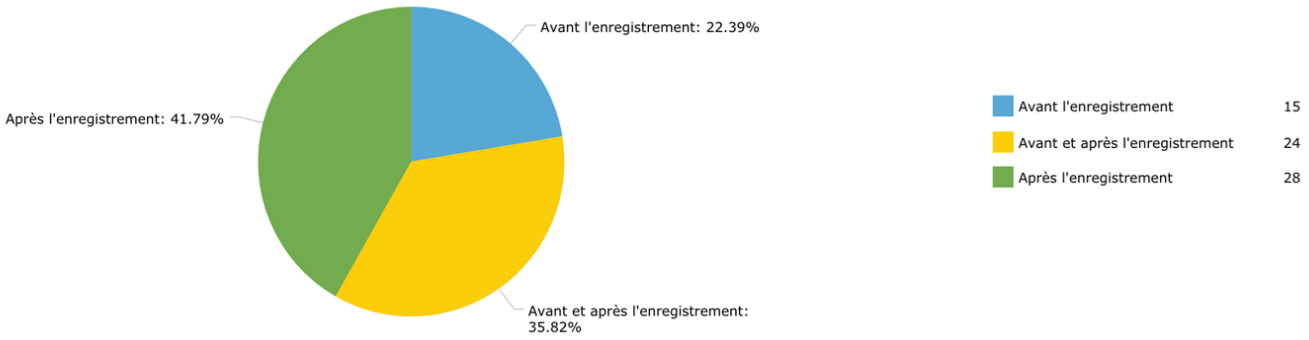


Annexes 4. Communication pour informer les soignants

Annexes 5. Utilisation des deux systèmes MHT et PSR pour un acte a risque

Acte 1 : Pose d'un cathéter

Répartition des prises de SHA en fonction de l'enregistrement de l'acte



Suivi de l'hygiène des mains lors de la réalisation d'un geste aseptique et d'une exposition à un liquide biologique

- Intervalle de temps entre la première détection d'un soignant et la première prise de SHA effectuée par ce soignant