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Human factors approaches to evaluating outpatient parenteral antimicrobial therapy services: a systematic review.

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Human Factors Approaches to Evaluating Outpatient Parenteral Antimicrobial Therapy

Services: A Systematic Review

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ABSTRACT

Background: The expansion in terms of available treatment options and models of care has led to a growing global momentum for outpatient antimicrobial therapy (OPAT) services. A systematic review was undertaken to explore Human Factors aspects relating to OPAT service delivery and to evaluate whether OPAT is amenable to description using the Systems Engineering Initiative for Patient Safety (SEIPS 2.0) model.

Method: Following a preliminary search, a search string was applied to four databases, including Medline, Cumulative Index of Nursing and Allied Health Literature, International Pharmaceutical Abstracts and PsychINFO. Inclusion criteria ensured only articles published after the year 2000 and written in English were accepted. The methodological quality of studies was assessed by three reviewers. Narrative synthesis was performed to uncover the key interactions between work system entities which underpin OPAT processes and outcomes as described using the SEIPS 2.0 model.

Results: A total of twenty-seven studies were deemed eligible for the final review. Of these, most described sample populations representative of the population under study, while duration of the studies varied from a few months to years. Some studies evaluated a single model of care whilst others evaluated all three currently available models. The breadth and scope of the studies included enabled extraction of rich Human Factors data describing barriers and enablers to service provision.

Conclusion: OPAT is a service which offers significant benefits to both patients and care providers. These benefits include patient satisfaction and wellbeing, as well as financial performance. OPAT is a

complex sociotechnical system, and a systems approach may offer the opportunity to enhance system design, maximising system performance. This review demonstrates that the service can be better understood using the SEIPS 2.0 model to identify key work system interactions that support performance.

Keywords: OPAT, Human Factors, SEIPS model, Service delivery

INTRODUCTION

Performance evaluation of healthcare services is essential in determining whether the anticipated outcomes in terms of patient safety, clinical care and supporting processes (including financial viability) are being met. Currently, it is typically assessed using key performance indicators such as bed turnover and occupancy rates, average length of stay, and hospital infection rate¹. A pragmatic way of positively influencing these indicators is to discharge those patients who are otherwise stable, and are in hospital solely for the purpose of receiving intravenous antimicrobials, to a home setting where they can receive outpatient parenteral antimicrobial therapy (OPAT). OPAT is defined as “the administration of at least two doses of parenteral antimicrobial therapy on different days without intervening hospitalization”². Initially developed in 1974 by Rucker and Harrison for treating a paediatric population³, OPAT has evolved into a dynamic and complex service used worldwide for the treatment of infections that require prolonged use of intravenously administered antibiotics in patients who are otherwise clinically stable and willing to continue their treatment as outpatients^{4,5}. This evolution has given rise to three complex models of care, which include the home (which may involve either a visit from a healthcare professional, but also includes self-administration), infusion centres and skilled nursing facility-based care environments. Each setting is therefore governed by individual and potentially diverse procedures, showing considerable variability in terms of patient/healthcare professional interaction, and having unique safety concerns as well as other differences^{2,6}.

A discipline gaining an evidence-based reputation for addressing healthcare complexity is systems thinking, which is at the core of Human Factors research and practice^{7,8}. Human Factors (also known as Ergonomics) is “a discipline which strives to understand the interactions between humans and other elements of a system. It is also a profession that applies theoretical principles, data and methods in practice, supporting the intelligent re-design of systems in a way that optimises both human wellbeing and overall performance”⁷. The compelling argument for its integration in national health services and policy is due to the often competing needs for ensuring sustainable patient safety procedures^{8,9} as well as the delivery of other desirable outcomes such as financial performance¹⁰. The systems engineering

initiative for patient safety (SEIPS) model was designed in 2006 by Carayon *et al.* to provide a usable Human Factors framework for application in healthcare systems¹⁵. Since then, it has been applied in a range of diverse settings. Furthermore, the model has evolved, with SEIPS 2.0 incorporating developments that are particularly valuable in addressing contemporary healthcare needs. The global response to the ‘safety crisis’ (first recognised in the Institute of Medicine report ‘To err is human’)¹¹ has been to attempt to reduce errors, reduce patient injury and to adopt an evidence-based approach to treatment¹². All these approaches emphasize that ‘system design’ is the key to such reductionist strategies. However, there is very little in the way of meaningful advice to support such re-design, reflecting a lack of understanding of the mechanisms that link system design to outcomes. This almost certainly results from an excessive focus on outcomes (and patient outcomes at that). Genuine Human Factors approaches are based on the understanding that outcomes are generated as a result of interactions between work system entities and that these interactions are driven by human work processes. In complex sociotechnical systems, the interactions are so many and often so unpredictable that the outcomes themselves can be hard to understand, a concept known as ‘emergence.’ While outcomes are ultimately what matters, they are difficult to influence positively without a deep understanding of system interactions that produced them. Human Factors approaches recognize that outcomes are influenced by human performance and that effective design can both support this performance as well as reducing hazards that threaten good performance. The interactions between the work system entities can be viewed as ‘inputs’ which are ‘transformed’ by human performance to yield outputs (including those related to safety). SEIPS 2.0¹³ focusses on these transformations, dividing them by type (physical, cognitive and/or social/behavioural) and in terms of the interactions of the people within the system (these are divided into ‘professional-only’, ‘patient-only’ and ‘patient/professional collaborative work’). The ‘work system’ element of the model supports exploration of how interactions between entities support human performance. The model also facilitates a macro-level consideration of the larger system, but also offers insight into the nested systems and multiple organizational layers within. Systems vary in size, and large systems are invariably made up of smaller systems. Such

‘nesting’ can be observed within the OPAT service: a nurse administering the patient’s treatment (micro), the OPAT team (meso) or the OPAT service as a whole (macro). This can also be seen in cross level interactions whereby for example the healthcare professional is at the frontline carrying out the tasks (micro) in response to a decision-making process which defines how the service will be offered (macro). A final consideration is the level of interaction occurring between macro and micro through cross level bridges (for example, communication is of critical importance at all levels¹³⁻¹⁵).

To date, SEIPS 2.0 has not been used to explore OPAT, which can be considered a complex sociotechnical system due to the high frequency and relative unpredictability of the interactions occurring between its entities. These entities include the people (e.g. patients, carers and healthcare professionals) and their environment, the organization responsible for the delivery of the service, the component tasks and the tools and technologies that support delivery. The patient (and carers) play an unusual role within the OPAT system, and the division of ‘transformations’ into ‘patient’, ‘patient-professional’ and ‘professional’ may be particularly useful.

The aims of this systematic review were (i) to critically appraise, synthesize and present the available evidence relating to adult OPAT services and (ii) to explore if the OPAT service is amenable to analysis using the SEIPS 2.0 framework.

To achieve these aims, two review questions were designed in relation to the amenability of the OPAT service to analysis using the SEIPS 2.0 model. The first question focused on the identification of systems factors, in terms of the SEIPS 2.0 framework which have been reported in service development, implementation and evaluation. The second question concentrated on the general outcomes of OPAT in terms of service development, implementation and evaluation.

METHOD

Protocol Development

The systematic literature review protocol was designed using the guidance offered by the PRISMA-P (Preferred Reporting Items for Systematic Review and Meta-Analysis) statement¹⁶ and submitted to The International Prospective Register of Systematic Reviews (Prospero) for consideration and registration¹⁷.

Inclusion/ Exclusion Criteria

Population

Patients, carers, policy makers, nurses, pharmacists, infectious diseases physicians named as stakeholders and involved in any stage of adult OPAT service development were included. Data were evaluated and implemented even if there was no specific mention of Human Factors. Data from studies relevant solely to paediatric populations were not included.

Types of interventions

Studies which reported any intervention occurring in the context of an OPAT service development. Articles describing implementation and evaluation were included.

Type of Comparators

Not applicable.

Outcomes

Studies which reported outcome measures of an OPAT service including (among others) the number of patients enrolled, adverse reactions, readmissions and treatment success.

Study design

No studies were omitted on the basis of study design. Studies applying qualitative (e.g. randomized controlled trials, observational design etc.) or mixed methods were included. Peer-reviewed primary research studies, systematic reviews and meta-analyses were included. Abstracts, letters and grey literature were not included.

Language

Only studies published in English were included.

Capture dates

Studies published from January 2000 up to June 2019 were included, as this captured the time period during which the application of theoretical principles of Human Factors had gained importance in the patient safety literature. Although healthcare Human Factors literature exists prior to this date, it almost entirely focusses on staff safety, such as safe handling of patients.

Search strategy

A three-step search strategy was utilized in this review, beginning with an initial scoping search of Medline and Cumulative Index to Nursing and Allied Health Literature (CINAHL) using search terms [(“outpatient parenteral antimicrobial therapy” OR “outpatient parenteral antibiotic therapy” OR “OPAT”) AND (“human factor” OR “ergonomic” OR “adaptation”)]. Note was taken of terms present in the titles, abstracts, keyword section and references to formulate the search string. This search string incorporated the Boolean operator “OR” for the sub-terms for each core term (namely Human Factors, Antibiotics, OPAT and Administration) and these searches were amalgamated together using the Boolean operator “AND” to create the final search string (Table 1).

[Table 1]

The search string was then applied to four principal databases, namely MEDLINE, CINAHL, International Pharmaceutical Abstracts and PsychINFO and the results were recorded. Criteria such as

the capture dates and language preference were inserted prior to running the search. Finally, the reference lists of the 121 papers identified were further reviewed.

Screening and selection

Titles, abstracts and descriptions of all studies identified during the database search were assessed for relevance to the review by two independent reviewers.

Data Extraction

Multiple reference tools were used to construct the data collection tool. These included The Joanna Briggs Institute data extraction form for experimental/observational studies¹⁸, the Systematic Reviews Centre for Reviews and Dissemination (CRD) guidance for undertaking reviews in health care¹⁹, the Cochrane public health group and the Cochrane guidance on extracting qualitative evidence.²⁰ The resultant tool captured general information about each study, including author and setting, participants, intervention, outcomes and system factors as described within the SEIPS 2.0 framework. It is important to note that almost none of the articles made specific reference to Human Factors and thus extraction almost entirely depended on the subjective opinion of the reviewers concerned. The Risk of Bias in Systematic Reviews (ROBIS) tool was used to ensure that the risk of bias was kept as low as possible²¹.

The SEIPS 2.0 model was utilized to categorize the systems factors, interactions and transformations (work processes) as described within the articles and, because of the subjective nature of the process, the final categorization was evaluated by all reviewers. Any conflicts were discussed to allow consensus to be reached.

Quality Assessment

All studies were assessed for methodological quality by two independent reviewers. Standardized critical appraisal instruments were used and adapted to suit the needs of the articles chosen. The Critical Appraisal Skills Programme (CASP) tools, as well as those described by Young and Solomon^{22,23} were modified to create the final quality assessment tool which covered subjects such as the articles' objectives, design, recruitment and data collection strategies, ethics, results, biases and Human Factors aspects which could be identified from the reported data. With respect to Human Factors, the reviewers also assessed whether entities and interactions could be categorized using the SEIPS 2.0 framework. Reviewers rated each question by giving the following answers Yes, No, Unclear, Not applicable or Partial.

Data Synthesis

The first step was to define the system entities and categorize the factors considered to relate to these entities. The next stage was to identify work processes and categorize these according to SEIPS 2.0 definitions. The final step was to identify interactions between the work system factors that had the potential to influence work processes and therefore outcomes. As with any complex system, OPAT factors were frequently assigned to more than one category. For example, the work system component 'person' could refer to the patient receiving the service. In this case, one 'person factor' would be the relationship between a patient's disease state and the suitability of the treatment selected. Similarly, the choice of antibiotic was considered to relate to 'task' (selecting the antibiotic), 'person' (having the skills and knowledge required to make this choice) and 'tools and technology' (the antibiotic itself) factors. Another example was the enforcement of standardized criteria which could be considered as an 'organizational', 'person', 'tool' and 'internal environment' factor due to local need to enforce policies, patient eligibility in relation to these criteria and whether or not the (patient's) residence meets the requirements as described in the criteria respectively. These steps are illustrated in Figure 1 below.

[Figure 1]

Results

[Figure 2]

Searching

The PRISMA chart in Figure 2 illustrates the results of each phase of the literature search. Of the 189 articles initially identified, 179 were drawn from the four main databases whilst 10 were identified from article references. Of these, 29 were duplicates and 122 did not meet the inclusion/exclusion criteria. 38 full text articles were assessed. 11 full text articles were removed because of a lack of relevance, leaving a total of 27 for final review. Critical appraisal and data extraction were carried out for each of these articles.

The number of participants was generally constrained by the study time frame or the setting chosen by the authors. For example, in the study published by Htin *et al.* despite the study period running from June 2002 to July 2011, because only patients diagnosed with infective endocarditis were considered for inclusion, the sample size was only 68 patients.³⁶ This contrasts with the study carried out by Barr and colleagues which covered a similar timeframe (January 2001 to December 2010), but included patients with a variety of disease conditions, and therefore involved a total of 2233 patients³⁷.

It is worth noting that, when reported, specified inclusion criteria reflected patient eligibility as articulated in guidelines, suggesting attempts to achieve a high standard of practice². These inclusion criteria included clinical stability^{29,33,49}, lack of psychiatric disorders²⁹, no history of drug abuse⁴⁹, the presence of family support²⁹, home telephone and transport facilities^{29,33,49}, completion by the patient of at least two days of OPAT delivery in the infectious disease clinic³² and consultation with an infectious disease physician prior to engaging with the OPAT service²⁷. Details of the study characteristics can be found in Table 2.

[Table 2]

Quality Assessment

As can be seen from Figure 3, most publications were able to satisfy the questions designed to assess quality. Positive responses are indicative of high quality for that aspect of the reported research. Moreover, an almost complete consensus was attained amongst the three reviewers. The question attaining the highest number of positive answers referred to the identification of aspects of the system which could be considered classifiable from a SEIPS 2.0 perspective (27/27; 100%). The question relating to clarity of the findings gained 26/27 (96%) positive responses, while almost all studies (25/27; 93%) were considered to have fully described their participant characteristics, collected data in an appropriate manner and to have clearly stated their findings in relation to the aims. The 'not applicable' option was only used once by the reviewers for the ten questions posed. Moreover, for those publications which lagged in terms of positive responses, there was a high proportion of partial rankings, especially in items relating to the research design and declaration of conflicts and bias. Overall, the quality of the included studies was considered high.

[Figure 3]

Data Extraction and Synthesis based on SEIPS mapping

Outcomes

[Table 3]

Most studies stated evaluation of the service as an aim, despite variability in the outcome measures chosen as performance indicators. Such indicators included safety and efficacy^{24,32,29,34,36,30,25}, frequency of readmission²⁷, presence/absence of certain care processes^{39,49,27,35,48,47}, quality of life³¹, patient satisfaction^{45,46,33,50}, cost effectiveness^{24,33,38,50}, treatment completion rates³⁸, failure^{28,40,41,42} and

expansion of the service^{37,43,44}. Due to the heterogeneity in terms of aims, settings and populations, the results described by the authors varied in terms of their reported outcomes (see Table 3). Some studies reported the rate of readmission, success, death and complications as described in Table 4.

[Table 4]

Also of interest is the range of healthcare professionals mentioned in the studies. One study described a team comprising physicians, nurses, a social worker and pharmacist³⁹, others made reference to physicians, nurses and pharmacists^{27,31,37,41,43,49} whilst some referred to a team composed of doctors and nurses only^{24,48,35,38,32,29,36}. Some papers merely referred to an 'OPAT team', making it very difficult to identify precisely those healthcare professionals involved in the service delivery. A few studies referred to other stakeholders, including the family physician^{33,50}, nurse care manager³⁹, medication courier²⁶, community nursing personnel^{31,26} and the clinical microbiologist⁴⁹. There was also the occasional mention of carers and their role in the delivery of the service. This largely referred to the importance of their receiving education about the service and skills needed to administer treatment^{37,49}.

Processes

A series of common processes are inherent in any OPAT service irrespective of the model of delivery practised and the presence or absence of a formal OPAT programme^{34,43}. The following sections highlight the professional work, patient work and the 'collaborative work' making up the work processes in terms of their physical, cognitive and social/behavioural elements as described by Karsh *et al.*,¹² Carayon *et al.*¹⁵ and Holden *et al.*¹³. Despite the broad spectrum of services offered, some processes were common to all studies. The first of these was patient selection, a process composed of a collection of tasks designed to determine the suitability of the patient as an OPAT candidate. These tasks include reviewing the patient history to assess the impact of comorbidities, and assessing the

potential impact of other constraints such as the suitability of the home environment as well as the physical capabilities of the patient, including – for example - their mobility etc. The eligibility of the patient is assessed in relation to both the model of care selected for that patient and what can reasonably be provided by the service provider. Once the referral to the OPAT team takes place, a treatment plan is devised with the plan including administration guidance. The involvement or otherwise of a formal OPAT team and/or an infectious disease physician depends on the specific setting. Collectively, completion of these tasks leads to the critical process of discharge of the patient from the hospital onto the service, which involves the patient crossing a service boundary. Once discharge to the service is complete, subsequent processes relate to the administration of treatment, taking blood samples and monitoring laboratory parameters to ensure safety and efficacy. The latter processes, together with those related to follow up (be it during a virtual ward round or a patient-doctor visit at the hospital) form a continuous cycle which is only broken when the patient is deemed fit to be discharged from the service. From the moment the patient is approached by a member of the OPAT team for enrolment in the service until the point of discharge, most of these processes represent collaborative work. Processes which describe purely professional work include the evaluation of a patient's eligibility to enter the service, the monitoring of laboratory results and follow-up procedures. The main processes are depicted in Figure 4.

[Figure 4]

Professional Work

[Table 5]

Collaborative Work

[Table 6]

Patient Work

[Table 7]

Despite the lack of Human Factors reporting, extraction of factors relating to the OPAT work systems as described in the 27 articles was undertaken and the results presented in Table 8.

[Table 8]

In Table 9, the most frequently reported key interactions between these factors are highlighted

[Table 9]

Discussion

The papers identified covered a range of OPAT models, disease conditions, age groups and country settings which effectively supported a partial SEIPS mapping, yielding valuable information to support practitioners involved in the design and delivery of OPAT services. This value was further reinforced by the high methodological quality of the papers selected for the review. Perhaps unsurprisingly, given the relative infancy of the discipline in healthcare, almost no direct mention of the term ‘Human Factors’ was made in the studies reviewed. An exception to this was the work of Keller and colleagues^{25,26}. These articles specifically mention the term, and their work describes a task analysis approach to risk management in OPAT delivery. These authors refer to the SEIPS model, but while this has been used as a framework to support the development of tools to explore aspects of the OPAT system, they do not present a complete SEIPS analysis. We believe that this current work is unique in terms of describing the OPAT service through a SEIPS 2.0 lens, suggesting the service is amenable to mapping in this way.

Processes

Processes which involved Professional Work

Patient selection appeared to be the most important cognitive process carried out by professionals within the OPAT service context. In fact, three out of six processes reported by Gilchrist *et al*, specifically focused on this aspect, including the patient's eligibility, their acceptance on to the service and assessment by the team²⁸. Based on the outcomes of an assessment of the patient's mobility and capability for self-administration, a healthcare professional must decide on the most suitable OPAT model. This cognitive process - involving knowledge, forethought and problem solving - was reflected in an apparent decision to avoid certain patient cohorts reflecting an desire to achieve high success rates with few adverse events, which is a behavioral process^{32,36,37,40}.

The most frequently reported physical process carried out by professionals was the administration of antimicrobial agents. The ability of professionals to access patients across a range of physical environments depending on the model of delivery^{38,44} (a physical process) alongside their having the necessary skills to administer medication via a variety of vascular access devices (e.g. peripherally inserted central catheter; PICC)^{44,48,45} could together be seen to enhance the overall culture of service provision (a behavioural process). In a scenario where a patient is difficult to reach daily (a physical process), the ability of the professional to teach the patient self-administering techniques (a cognitive process) is an important part of empowering patients to start managing their own condition (a social/behavioral process) and overcome the constraints imposed by geographical location^{37,48}.

Requesting (and charting the results of) laboratory monitoring of patients was seen to be an important physical process as it contributed directly to healthcare professionals' informed decision-making in relation to the management of their patients (a cognitive process)^{24,35,26,47}. This in turn drove a social/behavioral process which ensured that the need for a systematic method of accessibility to laboratory results was highlighted,⁴³. It could also be seen that continued laboratory monitoring assisted OPAT directors in monitoring readmission rates^{34,43,30} and ensuring clinical governance related to OPAT is maintained³⁷.

Processes which involved Collaborative Work

The availability of a telephone OPAT helpline supported the physical aspect of the communication process, which is essential for both the answering of patient queries and for the monitoring of patients by healthcare professionals^{36,46,45,26}. This communication, in turn, supported the cognitive process of validating the original decision made between these stakeholders to enter the OPAT service. Moreover, professionals could be seen to take person factors such as patient age, dexterity, co-morbidities and presenting infections into consideration (a cognitive process). This aspect promoted the social/behavioral aspect of communication between stakeholders thus supporting better overall outcomes^{28,49, 26}.

Other physical processes involved the professionals' visits to patient residences and patients' visits to the hospital (or centre offering the service)³⁴, getting patients' consent and endorsement prior to prescribing toxic treatment,³⁴ the reporting of adverse events³⁵, removal of the vascular access device²⁶ and the decluttering of the residence prior to a home visit⁽⁴⁶⁾.

Processes which involved Patient Work

As with the professional group, 'treatment administration' also appeared as a 'patient only' process as part of the self-administration mode (with or without the assistance of family members or carers)^{39,30}. Patients were taught the necessary skills to perform administration in their home environment^{37,44,45,30} (a cognitive process). Its success in turn empowered patients, promoting a positive culture favouring OPAT admissions driven by the patients' positive attitudes^{33,49} (a social process).

Certain physical processes were attributed to specific cohorts. For example, geriatric patients were seen to present at the emergency department or to telephone OPAT team members for assistance more frequently³⁹. This proved to be beneficial in that it appeared to help reduce worsening mental function

²⁹ (cognitive) and encouraged patients of this age group to accept admission to the service by ensuring family support, comfort in their home environment etc.²⁹ (social). Another ‘stand out’ cohort were intravenous drug abusers who frequently failed to attend follow ups and often misused intravenous devices which made them non-adherent to therapy (cognitive) leading to failed OPAT courses⁴³ (social).

Systems Factors as described by the SEIPS 2.0 Model

Through the SEIPS 2.0 lens, the OPAT service is viewed as a dynamic work system whose outcomes are the result of processes which, in turn, are underpinned by interactions occurring between various system entities. Using the example of administering treatment, it could be seen that a number of ‘task factors’ strongly interact with ‘tools and technologies factors’ which in turn interact strongly with ‘person factors’ such as training and expertise in relation to these tasks. These interactions could be seen to impact on the success or otherwise of processes in delivering outcomes.

Task Factors

With respect to the tasks described in the provision of the service, emphasis was placed on the enforcement of standardized patient selection criteria following individual assessment, and many studies strongly attribute the success rate of the service to this task^{32,29,35,36,38,53}. Studies also mentioned that improvements to the care process could be driven by an organizational strategy that supports the implementation of standardized channels for communication such as an electronic database, a tool/technology accessible to all, which can effectively support multidisciplinary meetings^{47,43}. The database was also seen to reduce the risk of erroneous antimicrobial prescribing going unnoticed and to allow close monitoring of blood laboratory results as well as supporting patient follow up^{32,27,34,37,41}.

In the study published by Miron-Rubio *et al.*, the efficiency of the healthcare professional was mentioned when referring to the ability to successfully administer more than one antibiotic during the same visit⁴⁸. This is an example of a key interaction between a task factor and a person factor.

Furthermore, Lane *et al.* went on to suggest that such tasks are additionally complicated by the external environment. For example, increased geographical reach of the service would put further strain on the work system³⁵. This would in turn influence the administration times - especially in the nurse 'outreach at home' model - and thus impact the overall efficiency of the service⁴⁹. This key interaction warrants further research as it is inherent in all OPAT services.

One problem noted in several studies was catheter complications, with better education for both the healthcare professional and the patient (especially in a self-administration model) considered key to reducing their incidence^{27,38,26,25}. Education and the need to take an interest was also stressed not only in terms of the patients, but also for informal caregivers who may be supporting a patient with a high medication burden due to other comorbidities²⁹. Self-administration introduces different risks into the OPAT service, and education is therefore considered an important element of risk management in this group⁴⁸. Rather than considering the traditional education approach, a Human Factors response would be to view this as a design problem and perhaps consider the tools/technology element by procuring more efficient and/or usable equipment, such as the use of elastomeric pumps instead of the gravity method of administration. Indeed, the SEIPS 2.0 model highlighted the fact that extent of training/education was not the only factor contributing to administration failures, but that the design and usability of the equipment was also an influencing factor.

A geriatric population is a cohort which might be expected to require more assistance from the OPAT team due to the potential for reduced capability, including, manual dexterity, mental capacity, and the need for physical assistance³⁹. The issue of patient compliance was tackled both by Hernandez *et al.* and Williams *et al.* in terms of e.g. missed appointments^{38,43} as well as non-adherence and misuse of intravenous devices⁴³. The patient's level of knowledge and skills to perform certain techniques was deemed important when assessing the success of the service³⁹ and, again, the skill level required will very much be affected by usability/design of equipment. Poorly designed equipment exerts high task

demands on the user, and when user capability is reduced, the mismatch between demand and capability can make poor outcomes much more likely. A failure to consider (and usability test) equipment is a common healthcare failing that can inadvertently exclude certain groups from a service. Groups such as the elderly, with the impact that age inevitably has on capability, are particularly vulnerable.

Person Factors

The concept of ‘person’ in the SEIPS 2.0 model identifies a number of individuals involved in the running of the OPAT service. Considering OPAT is based on teamwork, communication and equal contribution leadership model, the need for assigning roles and task responsibilities to all stakeholders (both a task and organizational factor) was deemed crucial, be it led by an OPAT director³⁴ or a designated, qualified team^{27,28,33,35,43,47}. Given the collaborative nature of much of the work, defining patient and carer roles and responsibilities is equally important. Education was a recurrent theme. Firstly, mention was made of the OPAT providers’ ability to act in an educator role, especially in the home model when patients are not in the presence of a healthcare professional all the time, unlike the inpatient setting. This is even more critical in the self-administration model, where the patient must shoulder much of the responsibility in terms of administration, sterility and other aspects.^{29,39,37,45} The need for education was also mentioned in respect of the referring physicians: These have an important role in selecting patients to minimise the likelihood of failures resulting from operational or clinical issues⁴⁹.

Finally, the physician’s knowledge and the importance of continuing professional development was highlighted by Williams *et al.*, especially when considering the potential impact this has on their making the correct treatment choice in terms of cost, frequency, administration, presenting and co-concomitant disease among others⁴³. The three studies published by Duncan *et al.* , Hitchcock *et al.* and Seaton *et al.* looked at the attitude of health professionals and the impact of this on outcomes. A proactive attitude, combined with a high level of knowledge, allowed them to take pre-emptive action to prevent a

readmission or complication. An example of this includes the decision to switch the patient to oral therapy^{40,42,49}. In contrast, Miron-Rubio *et al.* and Gilchrist *et al.* suggested that the ability to make a pre-emptive intervention was best supported by standardised monitoring practice combined with appropriate follow-up^{28,48}.

Provider satisfaction was highlighted in studies by Al Ansari *et al.* and Al Alawi *et al.* as an important outcome which in turn would influence all persons in the work system. It was suggested that the positive reinforcement produced by high satisfaction would further encourage physicians and healthcare institutions to widen their service provisions, such as expanding delivery models to accommodate all three OPAT options (hospital-based infusion centres, nursing outreach programmes to patient residences and self-administration by patient or carer)^{33,50,44}.

The need for good communication, as mentioned previously, was considered important. The SEIPS 2.0 model is particularly useful when it comes to considering communication within a system. Communication as an individual skill is undoubtedly a 'person factor' which can impact strongly on outcomes. Communication and non-technical skill development programmes can be useful here. However, complex sociotechnical systems are often not designed in a manner which supports effective communication. In this case, 'communication' can be considered a high-level, emergent outcome. It is important to understand the difference, otherwise communication failures may be responded to by providing healthcare professionals with non-technical skills training. If system design is the problem, this is unlikely to be successful, and possibly disenfranchises those who already have good non-technical skills. Gilchrist *et al.* describe the lines of communication that should be established and maintained, suggesting that communication issues within OPAT service delivery are more likely to be outcomes, rather than person factors. Important lines of communication included those between the patient and OPAT providers, OPAT providers and the relevant internal/external departments and the OPAT team members themselves. This study found that 57% of failures were identified as being related

to communication issues, which further supports the notion that poor communication is a system failing rather than an individual skill failing²⁸.

System factors attributable to patients included their underlying health. Despite the high overall success rates reported in the studies, readmissions were not uncommon, with complications relating to a number of different reasons (including adverse drug events, catheter and line infections)²⁷. Some failures even resulted from the severity of the infection in question rather than any adverse event³⁹. The frequency of these complications was further increased in the presence of co-morbidities which negatively influenced the achievement of a level of stability considered sufficient for discharge and treatment success^{29,40,42}. Compromising infections such as the acquisition of Methicillin-resistant *Staphylococcus Aureus* (MRSA) were also seen⁴⁹. An example of how these factors might combine could be seen in patients who, due to the presence of comorbidities, require parenteral nutrition. These individuals are at an increased risk of bloodstream infections which, in turn, is a risk factor for catheter related infections³⁹. This is an example of an interaction between the task factor of 'patient selection' with the person factor of 'individual patient characteristics' which, in this case, is the type of feeding required by the individual.

Social complications such as a change in the patient's residence³² and/or a patient's financial situation³⁸ were considered as key elements which could compromise outcomes perhaps, for example, leading to cessation of the programme. The study presented by Perez-Lopez *et al.* showed that a geriatric population potentially had much to gain from an OPAT service since it gives them the opportunity to retain their residential environment, social interactions and family commitments, physical space, dietary habits etc²⁹. Similar findings were reported in the paper published by Williams *et al.*, which suggested there was an increased sense of wellbeing, while Bernard *et al.* reported that their geriatric cohort were satisfied in terms of the treatment and the ability to maintain a normal schedule²⁴. Such groups can often be excluded from the service because of the multiple morbidities likely with older age and also a lack

of live-in carer support. Careful selection of antimicrobial agent may help – agents that only need to be delivered once per day would keep the care burden to a minimum.

Patient satisfaction was assessed as an outcome in three of the selected studies: Al Alawi *et al.*, who chose the short form patient's satisfaction questionnaire (PSQ-18)⁵¹, Al Ansari *et al.* who formulated a questionnaire³³ and Goodfellow and colleagues who used mental scores as a measure of mental health, and this was seen to link to overall satisfaction. Goodfellow *et al.* reported positive results in terms of reduced psychological distress and impaired social functioning related to emotional problems. These effects were seen to encourage the use of the service³¹. Satisfaction was also extrapolated using thematic analysis from the interviews performed in the qualitative studies performed by Twiddy *et al.* and Berrevoets *et al.*, when patients explained that despite their co-morbidities, OPAT had a positive impact on their activities of daily living^{45,46}.

Tools and Technology Factors

The importance of screening for MRSA was highlighted as it was associated with poor outcomes, irrespective of the length of treatment, age and diagnosis,⁴¹ thus emphasizing the need for advanced laboratory testing for this organism. Lane *et al.* remarked on the influence of having an adverse event reporting system whilst Durojaiye *et al.* commented on the importance of an in house database containing details of the patient courses provided by the service. These were dismally absent in most settings and are an important tool to have especially when considering the importance given to feedback as highlighted in the SEIPS 2.0 model^{35,47}.

Increased efficiency of service provision was attributed to the enhancement of tools and technologies used for administration, for example, the use of an elastomeric electronic infusion pump^{48,30}. Such enhancements theoretically permit a higher patient intake as administration times should be reduced.

Another example is the availability of technology for performing laboratory testing, which should support better clinical assessment⁴³. Moreover, a relationship was highlighted between low adverse event rates and close monitoring of patients, further emphasizing the need for optimal monitoring technologies, especially when the service is being delivered in patients' residences²⁴.

Most tools and technology factors related to the patient's residence and the patient's ability to use tools, maintain their sterility and resolve any complications, particularly during self-administration³⁹. This aspect was studied in considerable detail by Keller *et al.* as part of their OPAT hazard identification approach²⁵. This is example of another key interaction in the OPAT system, here between a person factor, a technology factor and an environmental factor.

Organization Factors

The provision of the service on an outpatient basis was seen to deliver positive outcomes for the organization in question, including reduced readmissions and incidence of nosocomial infections^{45,54}. Moreover, reduced cost burdens were reported, partly due to increased hospital capacity realized as a result of patients being discharged to OPAT, but also due to the reduction in the unnecessary use of medicines that was associated with medicine reconciliation by the OPAT team^{33,43}. The organizational crux of the quality of the service was recognized as the 'standard framework', one which encompasses guidelines, articulates and supports standard lines of communication. Other essentials of such a framework were considered to include standard procedures such as obligatory infectious disease consultation with a medical consultant prior to discharge, laboratory monitoring and follow-ups designed to pre-empt complications. The lack of more frequent standard monitoring prevents the early detection of adverse events, making interventions futile or overdue³⁵. Also considered to be important was the existence of designated personnel with clearly articulated roles, including the senior management team^{38,34,43,40}. Important facets of the service were highlighted, such as the need to address

patients' co-morbidities (such as achieving better diabetic control, or wound management among others). This was on a par with the need to ensure that patients complete their treatment⁴¹. Moreover, the provision of treatment at home, was recognised as an added benefit in terms of minimising the spread of certain infections such as *Clostridium difficile*⁴⁵.

Studies also stressed the need for an organization to adopt specific measurable outcomes to verify the success of the service, including frequencies of complications and clinical cure, patient satisfaction and readmission rates amongst others⁴⁰. Durojaiye *et al* went a step further by creating a predictive model based on commonly known OPAT variables to avoid unnecessary readmissions⁵⁴. It is considered that this high level of standardization - especially at the pre-discharge OPAT phase - will help the service thrive when faced with an increasingly heterogeneous population making use of it,^{27,34,35,42} especially as the range of anti-microbial agents considered for OPAT use increases³⁷. Other organization factors include patient selection. In the process map designed by Gilchrist *et al.*, 31 failure issues were attributed to this very first part of the service, providing further evidence that the eligibility criteria and pre-discharge phases are of extreme importance²⁸.

Another important organizational element revealed in the more recent literature is the level of flexibility of the service, notably the ability to adapt to the daily changes in staff workload without allowing this to impact on the patient's daily activities, which several patients described as a drawback of OPAT. Examples of how this might be dealt with include the use of longer acting microbials to reduce the number of visits required at the patient's home and thus increase their overall freedom. This is an example of how an organizational factor (sourcing of medicines) interacts with a tools factor (the dosing regimen of the antibiotic) and with a person factors (staff workload and patient wellbeing)^{45, 46}.

Environmental Factors

The OPAT service is influenced by two ‘environments’, the internal and external which can take the form of recommendations stipulated in guidelines^{2,30}(external) or the actual physical space in which the service is rendered (internal) for example an OPAT clinic³⁰, the hospital environment or the patients’ residence⁴⁵. Due to the variety of internal environments in which the service can be rendered (depending on model) studies have highlighted the importance of maintaining certain standards within the patient’s internal environment. For example, the study by Keller *et al.*²⁵ encouraged avoidance of extreme temperature at the patient’s residence to safeguard the integrity of the dressing whilst Voumard *et al.* commented that such measures will ensure the stability of medicines being administered through elastomeric pumps at home⁵²,

Strengths and Limitations

This systematic review set out to achieve an important goal in terms of understanding the extent to which Human Factors had been considered as an approach in OPAT delivery. Early scoping searches had indicated there was little or no literature to suggest this had been done. Consequently, the scope of the review was increased with the intent to categorize the extracted data using an established Human Factors and Ergonomics framework. Through this systematic review, factors inherent in the work system and influencing measured outcomes could be observed. It is also of interest to notice the level of overlap between the studies in terms of the factors identified. This is important as not all cohorts were the same - some varied in terms of disease condition, age, means testing, country etc., yet the same predominant issues kept resurfacing. Categorising factors according to the SEIPS 2.0 model enables stakeholders to identify generic enablers and barriers, allowing intelligent system re-design to support positive outcomes. All studies suggested patient selection criteria and stakeholder education were particularly important. The ongoing need to focus energy on education and training indicates that the system is not that well designed and thus would potentially benefit from a Human Factors approach.

Although the systematic review was limited by the exclusion criteria which only reviewed articles in English published after the year 2000, this study was guided by the ROBIS tool and inter-rater reliability assurances were made throughout. Moreover, it is important to note that it is the first of its kind, one which uses a Human Factors systems framework to explore the service provision of OPAT.

The robustness of the study was enhanced by the timeframe employed within the study, which supported the capturing of both proximal and distal outcomes of OPAT treatment, an important component of the SEIPS 2.0 framework. However, due to the differences between the studies (and the way in which they were reported) the contributions of specific interactions was difficult to quantify. Despite this limitation, the aim of the review was to evaluate the amenability of the service to the SEIPS 2.0 model, which proved successful.

The authors recognize that, in applying the SEIPS framework to published papers, system data is restricted to that which has been reported. A full Human Factors approach would explore 'work as done' within the OPAT system, rather than this 'work as reported.' 'Work as done' is best explored by gathering data from a range of sources, including direct observation, gathering of quantitative data through audit and the gathering of qualitative data to capture the experience of the system stakeholders. This approach will define the future phases of this work, in which the visiting nurse model currently being provided in Malta since October 2016 will be explored using the SEIPS 2.0 framework. The final step will be to map the factors extracted from the triangulated data sources onto the SEIPS 2.0 model and compare the findings with those of this review.

Conclusion

The systematic review sheds light on the numerous Human Factors aspects inherent in the provision of the OPAT service. Despite the high service success rates extracted from the studies, various aspects of

the service can be tackled to enhance other measurable outcomes which might have not been considered by institutions such as patient and provider satisfaction.

Despite the robust data identified in this systematic review, there is still a lot of research which needs to be done in terms of deciphering work system factors specific to the various OPAT models of care as well as to delve further into the experiences of patients who are the end users of this system.

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Table 1: Search Strategy

Core term	Sub-terms
Human Factors	1.1 human factor*
	1.2 ergonomic*
	1.3 task analysis
	1.4 system* analysis
	1.5 patient safety
	1.6 1.1 OR 1.2 OR 1.3 OR 1.4 OR 1.5
Antibiotics	2.1 anti-biotic*
	2.2 antibiotic*
	2.3 anti-bacterial*
	2.4 antibacterial*
	2.5 anti-microbial*
	2.6 antimicrobial*
	2.7 anti-infective*
	2.8 2.1 OR 2.2 OR 2.3 OR 2.4 OR 2.5 OR 2.6 OR 2.7
OPAT setting	3.1 ambulatory
	3.2 home
	3.3 outpatient
	3.4 out-patient
	3.5 3.1 OR 3.2 OR 3.3 OR 3.4
Administration	4.1 intravenous
	4.2 parenteral
	4.3 4.1 OR 4.2
Final Search	1.6 AND 2.8 AND 3.5 AND 4.3

Table 2: Extracted study characteristics

Publication Date	Oldest study: Bernard in 2001 ²⁴ Most recent: Two studies published by Keller and colleagues in 2019
Study Design	Retrospective cohort design: most studies except for: Controlled quasi experimental evaluation: Keller <i>et al.</i> , Expert panel: Gilchrist <i>et al.</i> ²⁸ produced a consensus statement which was used to map and identify risks associated with OPAT service delivery Prospective Investigative Design: used by Perez-Lopez <i>et al.</i> ²⁹ , Gardiol <i>et al.</i> and Goodfellow <i>et al.</i> ³¹ Retrospective cross-sectional design: Suleyman <i>et al.</i> ³² , Al Alawi <i>et al.</i> ³³ , Muldoon <i>et al.</i> ³⁴ and Lane <i>et al.</i> ³⁵
Population demographic	Opportunistic sampling: Muldoon <i>et al.</i> and Lane <i>et al.</i> ^{34,35} Purposive sampling: employed for all other studies.
Data Collection	Retrospective retrieval of data by using: Survey: Muldoon <i>et al.</i> ³⁴ and Lane <i>et al.</i> ³⁵ Patient files, case notes and/or accessing an electronic database.
Patient Cohorts	Specific patient cohort: the homeless ³⁸ , elderly ^{29,39} Specific disease conditions: skin and soft tissue infections ^{40,33} , bone and joint infections ^{24,41} or infective endocarditis ^{42,36} . Broad disease conditions: remaining 16 studies
Study timeframe	A short time frame: 2 months ²⁸ , 1 month ³⁵ A long-time frame: 9 years ^{36,37} , 12 years ⁴²
Study setting	Australia ³⁶ , USA ^{25,26,32,27,38,39,43,44} Canada ³¹ Europe ^{45, 30, 46, 47,28,29,37,40-42,44,48,49} East Asia ^{33,50} .
OPAT model	home-visiting professional ^{36,29,38,39,37,31,48,28,46,47,25} infusion centre model ^{32,33,50} multiple modes of delivery ^{24,27,34,35,41,44,49,45,30} self-administration ^{43,44}
Sample Size	Small samples: 43 patients ³⁸ , 82 patients ³¹ , 77 patients ⁴² Large samples: 4005 patients ⁴⁸ , 963 patients ⁴⁰

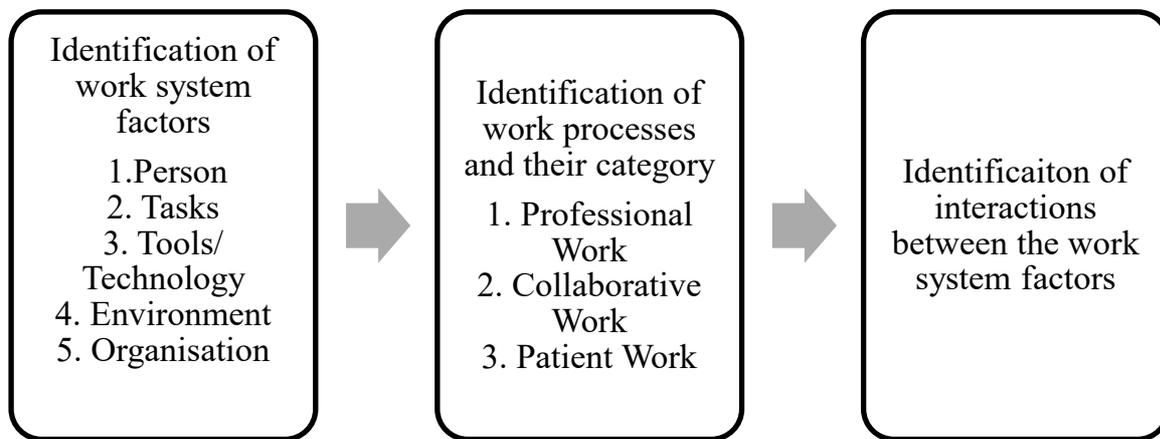


Figure 1 Data Synthesis Strategy

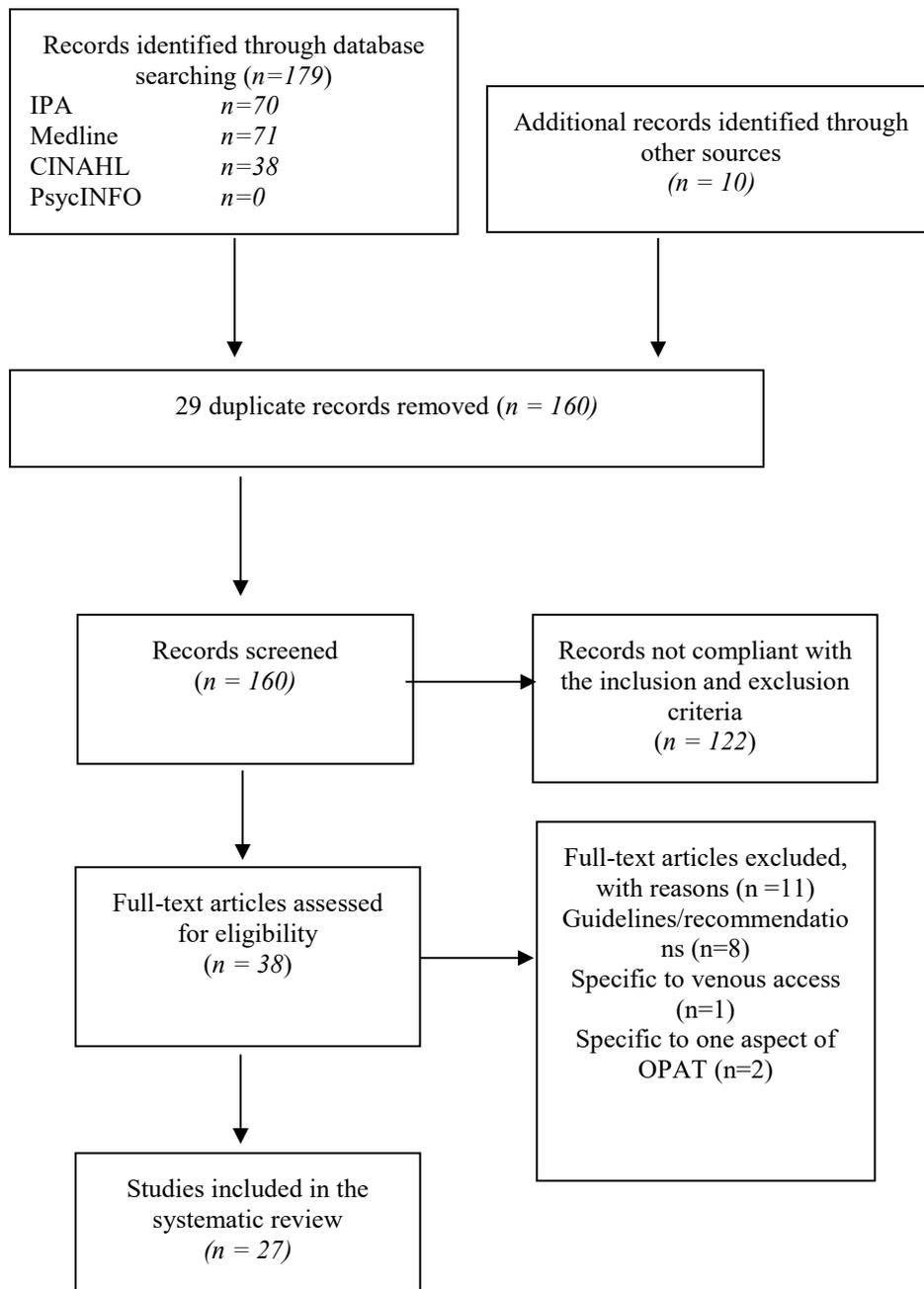


Figure 2 PRISMA Chart describing systematic review search process

Methodological quality of selected articles

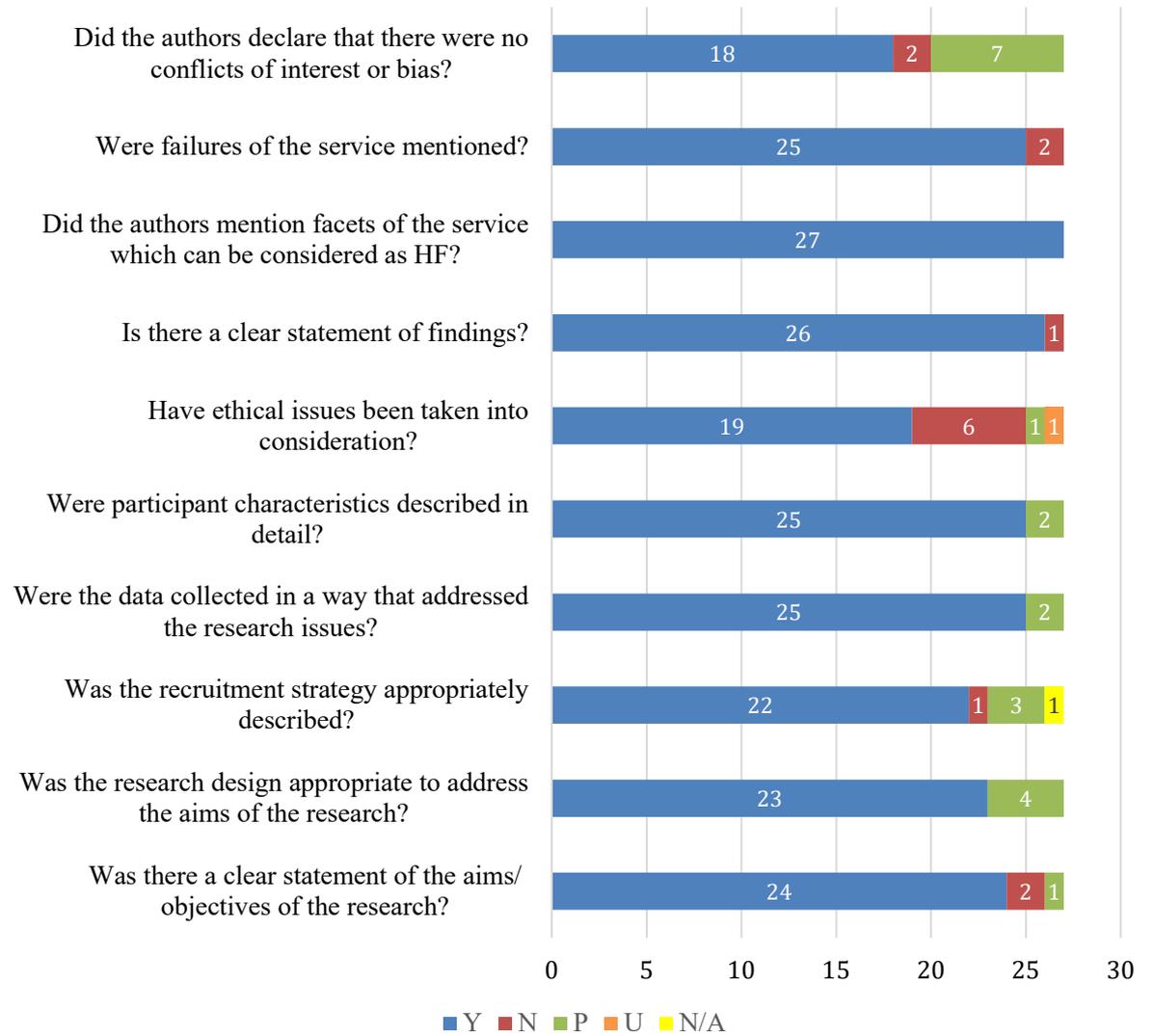


Figure 3 Stacked bar chart describing the methodological quality as captured by the quality assessment tool

Table 3: Outcomes from the 27 selected studies grouped according to SEIPS 2.0 framework

Outcomes
Patient
Satisfaction (33,50,44); reduced psychological distress (22); Inability to perform duties due to physical and emotional problems (31, 45); delivery at home achieved (24, 26)
Clinical outcome measures e.g. Throat soreness, fever, number of visits (33, 50)
Clinical efficacy e.g. Safety, rates of compliance, readmission (33)
Lost to follow up as course not completed (33); patient relocated (32); cost (32); severity of the infection (39)
Infection relapses (27); Severity of infection e.g. MRSA leads to failure irrelevant to the length of treatment, age or diagnosis (41)
Antimicrobial related ADRs (27,43, 42, 40); leading to switch or readmission (42)
Comorbidities which influence readmission rates (29,39,40) e.g. parenteral nutrition (39); acceptance rates (45)
Catheter related concerns e.g. misplaced line, occlusion (38,39), handling (25,26)
Concerns raised about a patient missing an appointment (38), travel (45)
Recognition of device handling problems especially in order population (39) and that self-administration increases risk of failure (48)
Improved quality of life and social functioning (24,31,46); because of patient involvement in decision making process (46)
Professional
Detection of antimicrobial prescribing errors (27)
Notification that a laboratory test has taken place helps the OPAT team ensure regular follow up is taking place (27)
Device complications (43)
Physician satisfaction ensures continuity of service (44)
Switching antibiotic or to oral therapy to avoid failure (40, 49)
Growing experience in appropriate antimicrobial choices reduces the duration of treatment (40)
Organisational
Cure rates; Deaths (34, 35, 47)
Saved bed days, cost cuts (33, 30); hospital capacity (43); positive mental change (31)

Reduced readmissions (33, 27); emergency department visits (34,48)

Cost cuts compared to inpatient stays (33)

Process map defining the roles of all those individuals involved in service delivery (27)

Scrutiny of OPAT model effectiveness as determined by outcomes (24, 38)

Recognition that early monitoring can increase awareness of clinical deterioration and pre-empt readmissions (24,35)

Information about healthcare associated infections (37,46) e.g. related to the devices (37)

Recognition of the importance of additional care services e.g. diabetes control (41)

Reduced nosocomial infections (48,49) transmission of MRSA, *Clostridium difficile* associated diarrhoea (49, 45)

Increased quality of communication between stakeholders (28) assisted with the setup of an OPAT structure (47)

Table 4: Treatment success and failure rates

Main Author	Readmission		Success		Death	Complications		Reason
						Complication (most common)		
Htin <i>et al.</i> 2013	3/68 (4%)		64/68 (94%)		0	1/68 (1.4%)		Line infection
Perez-Lopez <i>et al.</i> 2008	20/90 (22%) (>70 years)	13/55(23%) (<70years)	83/90(92%) (>70years)		0%	14/90(15%) (>70years)	9/55(16%) (<70years)	Phlebitis, rash, post antibiotic diarrhoea
Suleyman <i>et al.</i> 2017	2/122(2%)		120/122(99%)		0%	16/122(13%); 3/102(3%)		Adverse drug event; line complications
Hernandez <i>et al.</i> 2016	8/43(18.6%)		33/43(77%)		0%	7/43(16%)		Social concerns
Williams <i>et al.</i> 2015	67/115 (6%) antibiotics (data from 957 patients)(Period 1)	3/342 (1%) antibiotics (data from 229 patients)(Period 2)	NR	NR	0%	134/115 (12%) antibiotics; 279/115 (25%) antibiotics (data from 957 patients)(Period 1)	19/342 (6%) antibiotics; 14/342 (4%) antibiotics (data from 229 patients)(Period 2)	Drug related event; venous access complications
Barr <i>et al.</i> 2012	262/2233(11.7%) OPAT episodes		2063/2233(92.4%) OPAT episodes		8/2233 (0.4%) OPAT episodes	219/2233 (9.8%) OPAT episodes		Adverse drug event
Duncan <i>et al.</i> 2013	21/80(26.3%) episodes		55/80 (68.7%) episodes		2/80(2.5%) episodes	7/80(8.7%) episodes; 3/80(4.1%) episodes		Adverse drug event, other line complication
Miron-Rubio <i>et al.</i> 2016	328/4416(7.4%) episodes		4018/4416(91%) episodes		58/4416 (1.3%) episodes	241/4416 (5.4%) episodes		catheter complications
Seaton <i>et al.</i> 2011	58/963(6%) episodes		83/9963 (87.1%) episodes		NR	68/963(7%) episodes		Complication of infection process, significant adverse event

Hitchcock <i>et al.</i> 2009	23/303(7.6%) courses	278/303(91.7%) episodes	NR	2/303(0.7%) episodes	Adverse drug event
Gardiol <i>et al.</i> 2016	24/179(12%) episodes	168/179 (94%) episodes	0%	10/179(5.5%) episodes	Adverse drug event
Durojaiye <i>et al.</i> 2018	265/3812(7%) episodes	3357/3812 (88.1%) episodes	2/3812 (0.1%) episodes	265/3812(7%) episodes	Adverse events, line related complications

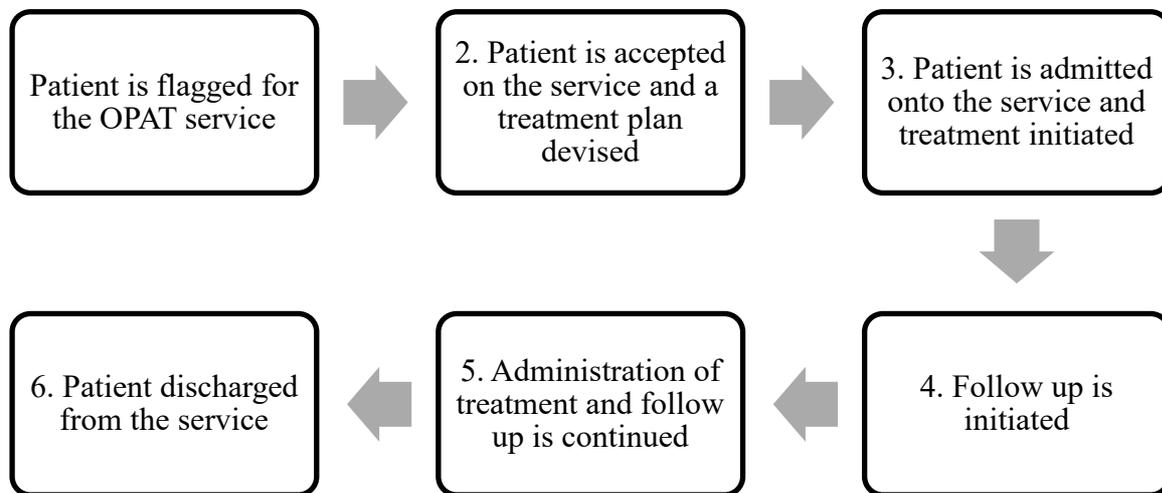


Figure 4 The generic processes involved in rendering an OPAT service

Table 5 The physical, cognitive and social processes relating to ‘professional work’ (as described by the SEIPS 2.0 model) pertaining to each phase of the OPAT service

Service Phase	Physical	Cognitive	Social
Patient is flagged for the OPAT service	Assessment of OPAT workload to evaluate whether the team can take on another patient (47)	Selection of the patient according to the institution’s eligibility criteria (40, 36, 32, 37);	Communication with all stakeholders involved in rendering the service (34,43, 46); Motivating professionals to cure more complex disease states (37)
Patient is accepted on the service and a treatment plan devised	Treating homeless patients e.g. using a respite shelter (38)	Teaching patients how to administer using aseptic techniques (37,48, 25, 26); Awareness of new pharmaceutical formulas which allow new administrations (29)	Decreasing the use of inappropriate therapy (34,35, 32, 43); Liaising with all stakeholders to successfully discharge patient onto the service (34, 43);
Patient is admitted onto the service and treatment initiated	Administration of treatment; Use of different administration techniques (44,48)	Improvement of transitional care processes e.g. reducing the errors that occur during antimicrobial prescribing (27)	Provide support to patients and caregivers (46)
Follow up is initiated	Requesting and charting of laboratory tests (24, 35)	Monitoring and inferences from laboratory tests (24,35, 26, 47)	Culture of regular monitoring set up to prevent adverse events (45)
Administration of treatment and follow up is continued	Drawing of blood samples to be sent to the laboratory for testing (26)	Addressing patterns of previous unsuccessful patient groups to pre-empt future readmissions (42)	Empowering patients (37, 48); Working towards lowering readmission rates through better follow up measures (27, 33, 47)
Patient is discharged from the service	Removal of vascular access device (26)		Planning of the service to generate higher success rates and fewer readmissions (34, 40, 36, 32, 37, 30); Achieving professional satisfaction (44)

Table 6 The physical, cognitive and social processes relating to ‘collaborative work’ (as described by the SEIPS 2.0 model) pertaining to each phase of the OPAT service

Service Phase	Physical	Cognitive	Social
Patient is flagged for the OPAT service	Assessment of skill set and dissemination of roles and responsibilities (26)	Knowing which factors cause poor outcomes e.g. older age, methicillin-resistant Staphylococcus aureus infection and diabetic foot infection (41)	
Patient is accepted on the service and a treatment plan devised	Taking consent prior to toxic treatment (34)	Deciding which administration techniques to use depending on discussions between professionals and patients (41); training vascular access device management (26)	Recognition that an appropriate OPAT structure can establish a treatment plan with patient (47)
Patient is admitted onto the service and treatment initiated	Delivery of medications by courier (26)	Monitoring of patient technique by team (26)	Establishing and maintaining communication channels between OPAT team members and patients (28, 49, 26, 45)
Follow up is initiated	Devising a schedule for withdrawal of blood samples and testing (26)		
Administration of treatment and follow up is continued	Ensuring patients attend hospital appointments(34); Reporting of adverse events (35)	Awareness of sterility procedures during administrations (26)	Ensuring patients are taking care of vascular access device and coping with daily life activities (46)
Patient is discharged from the service	Removal of venous access device (26)		

Table 7: The physical, cognitive and social processes relating to ‘patient work’ (as described by the SEIPS 2.0 model) pertaining to each phase of the OPAT service

Service Phase	Physical	Cognitive	Social
Patient is flagged for the OPAT service	Assessment of patient comorbidities in managing at home (45)	Reducing the onset of delirium and worsening social function especially in older patients (29); considering self-administration option based on patient skill set (45, 30); learning about the service prior to discharge (26)	Consideration of the impact of home visits on the patient’s freedom (46)
Patient is accepted on the service and a treatment plan devised	Ensuring adherence to prescribed therapy especially in intravenous drug abusers (43)	Recognising that offering the option of being treated at home may help in terms of patient responsiveness and morale (38,39)	Maintaining a home environment to include: supporting maintenance of familiar dietary habits, continuous family support and the ability to move about (29)
Patient is admitted onto the service and treatment initiated	Asking for the assistance of family members with administration techniques and devices (39); ensuring patients are aware how to tackle home hazards (25)	Improving psychological distress and social functioning, due to emotional problems (31,33) wellbeing (50, 43)	Empowering a culture that promotes more admissions onto the OPAT service (33,49)
Follow up is initiated	Ensuring that patients do not fail to show up at follow up appointments (43); ensuring travel arrangements are done for any appointments (45)		
Administration of treatment and follow up is continued	Seeking urgent care services especially a geriatric cohort (39); ensuring the vascular device is not misused (43); calling the infectious diseases pharmacist or physicians with questions especially older patients (39); ensuring the vascular	Ensuring the patients are correctly administering medications for the given amount of time (26)	Maintaining a normal daily routine (37,44); factoring in the support required from relatives (46); avoiding harm whilst performing activities of daily living (26)

	device is kept safe from home hazards (25)		
Patient is discharged from the service			Maintaining a normal daily routine (37,44)

Table 8: Extracted work system factors from the selected articles

Work System Factors

Tools/Technology
Eligibility criteria specific to the ear, nose and throat department (33)
Choice of drug based on profile/clinical condition/penicillin resistance (33) e.g. Ceftriaxone
Consideration of various routes of administration (33)
Improved medical devices and technologies (37,43) elastomeric pumps (48, 30)
Adaptability of the service allows more intravenous medicines to be administered (37)
New treatment options allow more conditions to be treated (37)
Patient/carer capability to self-administer (30) increases range of drugs and frequencies (48)
Tasks
Written instructions to go to the emergency department if adverse event occurs (50)
Eligibility criteria (33) Patient Selection (33, 36, 29, 32, 35)
Assistance by family/carer with medication administration (29); travelling to avoid delays in administration (25); understanding information (46)
Monitoring (24) daily (33) by the infectious diseases' physician (18) of the patients' clinical assessment and laboratory parameters (50, 34, 43, 35, 37)
Complexity categorisation depending if they are short or long treatments (50)
Patient follow up (34, 41, 28, 45)
Treatment selection with respect to cost, efficacy, frequency of administration, comorbidities etc. (43)
Education for patients/carers for performing infusions, importance of sterility (36, 39, 45)
Patients/carer capability in performing infusions, importance of sterility (39) daily activities with a indwelling line (25)
Travelling to appointments (45)
Person

<p>Eligibility e.g. Comorbidities (diabetes mellitus, hypertension, obesity, chronic obstructive pulmonary disease, asthma) (33) cardiac, renal (42)</p> <p>Eligibility based on specific clinical guidelines (33, 50)</p> <p>Eligibility e.g. Inability to swallow (33)</p> <p>Willingness to deal with multiple conditions (33, 50); willingness to accept service if provided with more information about treatment given (45)</p> <p>Knowledge, skills and ability to perform before the patient is discharged on the service (27, 29, 45)</p> <p>Patient's age (29)</p> <p>Patient willingness to be offered service (44, 46, 30), hesitation to leave inpatient setting (31, 45)</p> <p>Emotional impact of having an indwelling device (45, 46)</p>
<p>Organisation</p> <p>Referrals from medical, surgical and emergency departments (48,50); avoidance of delayed transition from hospital to residence (46)</p> <p>Multidisciplinary OPAT team with the necessary training and skills (50, 35, 40, 42, 47)</p> <p>Education for referring institutions to avoid their refusing eligible patients (49)</p> <p>Provision of formal guidelines (38)</p> <p>Channels of communication (35) involving infectious diseases specialists (34, 46) Electronic databases (43)</p> <p>Role of the OPAT director to decide which measure to use to monitor measure outcomes (34)</p> <p>Move towards community-based model to decrease bed occupancy (30)</p> <p>Involvement of infectious disease physicians prior to discharge (35)</p> <p>Lack of a reporting system for errors (35), lack of an in house database (47)</p> <p>Other medical services e.g. diabetes control, wound management, nutritional support (41)</p> <p>Flexibility of provider avoids limiting patients' daily activities (46, 47)</p>
<p>External Environment</p> <p>Guidelines e.g. centres for disease control and prevention guidelines (33)</p> <p>Referral from private entity to maintain treatment (33), referral from a general practitioner (50)</p>
<p>Internal Environment</p>

OPAT Clinic (33)

Geographical distribution of patients (35)

Influence of this on administration times (49)

Versatility of the service allows more intravenous medicines to be administered (37)

Patient or carer model versus infusion model (44)

Home environment that guarantees personal safety (45) and that of the access device (25)

Hospital environment supporting transmission of *Clostridium difficile* and MRSA (45)

Avoidance of extreme temperatures, dirt, pets and measures to declutter residence (25)

Table 9: Key interactions of the most frequently extracted work system factors

Work System Factors	Factor Descriptors	Key interactions
Tools/tech Factors- T1, T2	T1 Design and efficiency of medical devices and technologies used to administer treatment	Tas4, P2, P3, EE2
	T2 Accessibility of medical devices and technologies to perform laboratory testing from blood samples	Tas2, Tas3, P3
Tasks Factors- Tas1, Tas2, Tas3, Tas4	Tas1 The need to ensure that patients are selected in line with international OPAT guidelines	P1, P3, EE1, O1, P2, O2, IE1
	Tas2 The requirement to ensure regular patient laboratory monitoring and clinical evaluation	Tas3, P2
	Tas3 The importance of carrying out regular patient follow-up and re-evaluation by healthcare professionals to assess patient's prognosis	P2, O2, IE1, P3, O3
	Tas4 The need to educate patient/carer about the service and their involvement with the professionals offering the service	P2, P3, O2
Person(s) Factors- P1, P2, P3	P1 Patient eligibility due to comorbidities such as diabetes mellitus, hypertension, obesity, chronic obstructive pulmonary disease, asthma, cardiac, renal	
	P2 Healthcare professionals' knowledge, skills and ability to provide OPAT service	O2, O3, EE, EE2
	P3 Patient willingness to be offered service and leave inpatient setting	
Organisation Factors- O1, O2, O3	O1 The organisational need to ensure patients are discharged from hospital onto the OPAT service	O2, P1, O3
	O2 Setup and maintenance of an appropriately trained and skilled multidisciplinary OPAT team	EE1
	O3 Existence of standard channels of communication between healthcare professionals to ensure seamless care	
External Factors- EE1	EE1 Referral from private institution to maintain treatment e.g. GP clinic	
	EE2 Geographical distribution of patients influences administration times	
Internal Factors- IE1	IE1 Physical environment depends on the model of care (i.e. infusion centre, patient residence etc.)	