RFID-Based Healthcare Workflow Management in Sterile Processing Departments

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Abstract

Appropriate cleaning, disinfection and sterilization of reusable medical equipments (RMEs) in the Sterile Processing Department (SPD) are important to reduce healthcare acquired infections (HAIs) and person-to-person transmission. Currently, healthcare facilities utilize Standard Operating Procedures (SOP’s) following manufacturer’s instructions to guide staffs in SPD to complete the reprocessing procedure thoroughly and consistently each time. However, it is hard to ensure that operation steps are in proper manners by physical observations since there are no effective solutions to automatically monitor, trace, and verify the performance of SPD dynamic workflows. Through an enhanced, interdisciplinary understanding of business process management in healthcare enterprises, we design and develop an innovative framework of real-time healthcare workflow management in SPD. RFID-enabled intelligent objects are assigned to automatically capture the real-time data from multiple resources and RMEs. SOA-based workflow system is used to define and execute a flexible reprocessing and supply procedure from soiled RMEs collection to ready-to-use RMEs distribution. Via supervising the instant messages about the performance status of SPD operation processes, compliance check and smart rerun scheme are achieved by an intelligent rule engine to prevent and remedy delinquent operations.

Keywords: Healthcare Workflow Management, RFID, Patient Safety, Healthcare Systems

1. Introduction

Patient safety is one of the nation’s most pressing health care challenges. With the staggering numbers of patients harmed and killed by medical errors, which impacts 1 in every 10 patients around the world [1], the World Health Organization calls patient safety an endemic concern. Healthcare-associated infections (HAIs) are a major threat to patient safety and are among the most common adverse events in healthcare. Many of these HAIs are due to unclean reusable medical equipments (RMEs), which come directly into contact with patient skin, blood and other body fluids and tissues. For example, patients are at increasing risk of infection from invasive RMEs, such as endoscopes that are inserted into patient’s body and look inside a body cavity or organ.

Sterile Processing Department (SPD) is one of primary departments in a hospital, which has a separate and distinct area with specialized expertise and direct responsibility for both reprocessing soiled RMEs and providing clean and sterile RMEs to patient care areas. In most of Veterans Affairs medical centers, SPD is typically divided into three major areas: 1) decontamination area, where soiled RMEs that are collected from several clinics, such as dental clinic or operation rooms, are cleaned and disinfected; 2) preparation area, where machine-washed RMEs are packaged and labeled for steam or gas sterilization; and 3) case cart area, where ready-to-use RMEs are stored in the aseptic SPD inventory, and then retrieved into case carts according to the required medical equipment list for each patient’s treatment.

Most healthcare facilities design Standard Operating Procedures (SOP’s) from diverse manufacturers and models of the medical devices to guide staffs to complete the reprocessing operations thoroughly and consistently. These paper-based documents are normally posted as operation principles on the whiteboard of SPD where technicians could read the requirements of each operation. However, current practices still suffer intractable problems from several limitations when monitoring and controlling operation processes in SPD. As an executor to reprocess the
soiled RMEs, challenges happen that SPD managers cannot efficiently monitor and trace the reprocessing workflows running in the SPD floor. Errors could occasionally occur, such as technicians might skip some required steps, the chemical biological or temperature indicators of reprocessing environment are not standard or even the workflow routine which SPD technicians follow is not correct. Without displaying the real-time status of each operation in the reprocessing line, it is hard to make production control to streamline the cooperation of technicians and machines in different working areas. Consequently, the amounts of work-in-process items are stocked in the temporary inventory where the environment is not strictly aseptic. Some of the previous operations have to be duplicated. As a result, the reprocessing cycle time is increased. As a supplier to provide ready-to-use RMEs, SPD also needs to face the challenges in the dynamic medical environment. Typical problems are incapability to satisfy the unexpected demands, delay to supply, weak production plan to handle the exceptions to normal workflows when emergent orders arrive and inefficient expiration control to ensure expired RMEs off the shelves in the SPD inventory.

Many problems are compounded by lack of effective operation management with timely, accurate, and consistent data and automatic identification and localization mechanisms of RMEs and reprocessing resources. For example, SOP requires endoscopes should be washed for 10 minutes in a sonic machine in the decontamination working area. In practice, there is no sufficient time record to guarantee that the soiled endoscopes stay within a sonic machine for the required time length. If this sonic machine cleaning is not performed properly, the whole reprocessing procedure should be blocked at this step until the cleaning results of endoscopes comply with SOP rules. A surgery case has to be cancelled since a surgeon found that there were still tissues of previous patients on the scalpel. Based on survey results from our site visiting in John D. Dingell VA Medical Center, Detroit, SPD technicians typically spend 2-3 hours per day on looking for misplaced, lost, or mislabeled items physically. This non-value added operations delay the reprocessing procedures and reduce the efficiency of SPD operation management.

Consequently, healthcare professionals and managers anticipate an appropriate and deliverable approach to reengineer an SPD business process, and visualize, trace and control its execution. However, the methodology for SPD management is still in its infancy for healthcare management engineering. Few deliverable solutions and academic research have focused on this topic. This motivates us to explore an innovative method to improve operation management in SPD.

In this paper, we propose an RFID-based healthcare workflow management technology as one of attractive options to overcome the above limitations. According to Georgakopoulos et al. [2], workflow technology facilitates business processes management by providing methodologies and software to support the industry for modeling, reengineering, and executing business processes. It aims to track the routines of business processes, display the performance of each step, streamline process execution, and liberate human actors from routine work. These advantages of workflow management technology could assist an SPD manager to handle the problems in executing reprocessing procedures. Recent developments in wireless sensors, communication, and information network technologies (such as RFID, Zigbee, Wi-Fi, Bluetooth or Infrared) have provided a new opportunity to automatic capturing and managing data from the business process. Healthcare is considered as one of the most potential and successful deployments of RFID technologies for tracking medical assets, managing inventory and monitoring processes [3]. Specific sensor tags could record the significant indicators about working environment. This RFID-based healthcare workflow system (RHWFS) will provide a transparent operation management for SPD, which will facilitate the flexibility and adaptability to deal with dynamic demands and operations.

The main contributions of this paper are summarized as follows:

a) We explore the key problems and define the specific requirements of SPD management based on its two functions for a hospital: reprocessing execution and ready-to-use RME supply.

b) We develop a three-level framework of an RFID-based real-time SPD operation management system. As one of main subsystems, an SOA-based healthcare workflow system is designed to support the design, editing, execution, monitoring, and management of healthcare business processes in the sterile processing department.

c) We integrate RFID technologies into our SPD operation management system as an automatic data collection solution to support the real-time tracking and monitoring of locations, expiration dates, inventory level and other status of RMEs and several indicators of washing, disinfecting, and sterilization machines.
The rest of this paper is organized as follows: a) a brief review of SOA-based workflow management and RFID applications in healthcare; b) a deep exploration of key requirements to performance management in SPD; c) the overview of three levels in RFID-based real-time SPD operation management system, d) a description of the proposed infrastructure about SOA-based healthcare workflow system in SPD, and e) concluding remarks on the study and future research.

2. Literature Review

2.1. SOA-based Workflow Management in Healthcare

Workflow management is the computing perspective of business process management and designed to define, manage, and automate a procedure according to a set of business logic rules [4]. Currently, workflow technology is explored as diverse and rich technologies applied to numerous industries, such as e-commerce [5], virtual company [6] and manufacturing systems [7]. The integration of Business Process Management (BPM) and Service-Oriented Architecture (SOA) is considered as a promising solution to support dynamic and flexible work practices by registering, discovering, and combining reusable services [8]. Hu et al. presented an SOA-based adaptive workflow framework to handle the emergency event in Tourism Information Change Management and provide relative solution [9]. Cui et al. deeply explored the advantages of using SOA to develop the reference architecture for scientific workflow management systems [10]. Medicare and Medicate are considered as a potential field to more readily see the benefits of SOA-based workflow management since the workflow of medical cases are dynamic and unpredictable. Juneja et al. concluded that a service oriented architecture (SOA) can improve the delivery of important information and make the sharing of data across a community of care practical in cost, security, and risk of deployment[11]. Ardissono et al. presented the architecture of a framework integrating workflow management and context-aware action execution to support the personalized management of medical guidelines in home healthcare assistance services [12]. Emanuele et al. explored the opportunities of workflow technologies in clinical, operational, financial and administrative processes for healthcare [13]. Reijers et al. extended previous work on workflow and flexibility patterns and presented a methodology to discover, explore, select, and realize processes that possess the required degree of flexibility in the healthcare domain [14].

2.2. RFID in Healthcare

An RFID system can be represented as a multi-layer system composed by RFID tags that capture encoded data onto an integrated circuit and an antenna, readers that use radio signals to communicate with the tags and a middleware that interprets and manages the real-time information [15]. Healthcare is believed to be ‘the next home for RFID’ [16] after its successfully improvement in supply chain visibility, operation efficiency, and asset management [17]. As Fisher and Monahan stated, RFID is an emerging technology that is quickly becoming the standard for hospitals to track valuable assets, identify and locate patients, and manage medical personnel [18]. There is a great potential for improving the quality of medical services and increasing the productivity of value-added operations [19]. Vilamovska et al. summarized preliminary classification of healthcare RFID applications, which are patient safety / quality of care, pharmaceutical application, management of devices, supplies and biological material, and patient and healthcare personnel support/management [20]. Turcu demonstrated a successful RFID deployment example in emergency room. Effective treatment time is saved by reading the accurate medical history of unconscious, incoherent and unaccompanied patients from an RFID wristband [21]. Koh et al. designed the application of RFID to detect and control counterfeit drugs in pharmaceutical logistic management [22]. Because of the unpredictable service demand and the complex infrastructure of hospitals, quickly locating the critical items with high utilization numbers has been one of the perpetual problems in the healthcare service industry [23]. Bendavid et al. proposed a framework to redesign the replenishment process of medical supplies with RFID and approved a 2-bin ‘e-kanban’ replenishment system [15]. Ma et al. proposed a hybrid framework and roadmap to implement Real-time locating system in hospitals according to the theory of Information System Design Theory, Lean Management and Task-Technology Fit [24].

Although previous researchers and practitioners have provided useful insights in the adoption of SOA-based workflow management and RFID technologies in multiple fields, few discussions have focused on combining these concepts in business process management for healthcare facilities, especially the real-time management and control of SPD operations, which have specific operation requirements as described in the next section.
3. Key performance requirements in Sterile Processing Department

The long-term objectives of business process management in SPD are to reprocess the right soiled RMEs at the right working areas by the right operations and supply them to the right end users at the right time. In order to adopt workflow technologies successfully in SPD to facilitate monitoring and controlling of reprocessing operations, we identify the following seven key performance requirements for an RHWFS.

**R1: Event Signature:** Skipping imperative steps and operating based on wrong SOP rules are two significant errors which must be forbidden in SPD process management. It requires SPD manager to cautiously monitor the real-time status of each activity execution and the whole workflow execution. In the RHWFS, event signature should be designed as a process status tracking tool to capture and sign a change of the business process status in SPD. It aims to support the visualization of effective workflow control and ensure all required tasks to be completed according to a right SOP operation routine. An example of event signature table for activity execution and workflow execution is as follows:

<table>
<thead>
<tr>
<th>Activity Execution</th>
<th>Workflow Execution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initializing</td>
<td>Creating a flowchart based on SOP</td>
</tr>
<tr>
<td>Executing</td>
<td>In the Process</td>
</tr>
<tr>
<td>Finished</td>
<td>Completed</td>
</tr>
<tr>
<td>Verifying</td>
<td>Approved</td>
</tr>
<tr>
<td>Cancel</td>
<td>Delete a step</td>
</tr>
<tr>
<td>Error</td>
<td>Exception control</td>
</tr>
</tbody>
</table>

**R2: Compliance Check:** Nonconforming operations in SPD reprocessing and distribution procedures will increase the risks of bacterial contamination to RMEs. SOP describes the requirements of each step in detail, such as operation time, temperature value within clean machines. In the RHWFS, compliance check between SPD operations and SOP standards should be automatically executed by an intelligent subsystem. It aims to remind SPD technicians when such a check fails and help them to analyze the reasons and the consequential influence by this delinquent operation. If approved, the workflow will continue to be executed automatically according to predefined routines.

**R3: Smart Rerun Scheme:** In practice, one of remedial reactions to operation errors is to duplicate the previous steps of the reprocessing procedure. As we know, redundant duplications will increase the workload and cycle time in SPD and waste reprocessing resources. However, insufficient duplications could not reach the objectives of cleaning, disinfection and sterilization. In RHWFS, the intelligent selection and execution of optimal rerun steps should be included as a smart function. It aims to guide the SPD staffs to make up the nonconforming operations.

**R4: Effective Control of WIP inventory:** Physically tracing the inventory level and locations of Work in Process (WIP) RMEs is a time-consuming operation for SPD technicians. This inefficient WIP management will increase the amount of WIP items, require larger storage space and carry an inherent risk to shorten RMEs’ shelf life. Sometimes, a rerun operation will be invoked to deal with long-time buffered WIP items. In the RHWFS, RFID-based automatic data collection is deployed to record the inventory level, location and stocking time duration of WIP items. It aims to assist SPD technicians to closely control their working items and streamline their operations for cycle time reduction.

**R5. Failure Handling:** Machines might decay and software services might fail due to their complexity. Such failures should be processed to resume operations or prevent unclean RMEs. Multiple types of operation failures could occasionally happen in an unforeseeable way when executing a workflow. In the RHWFS, a function should be developed to provide the support for failure monitoring at multiple levels. It aims to catch, localize and handle exceptions automatically or with minimal human intervention. For example, when the temperature indicator of steam sterilization machine does not correspond to the required value, an alarm message will send to SPD staff for instant reminding or temperature could be automatically adjusted.

**R6: Adaptive Planning:** Under the complex and dynamic healthcare environment, the schedule of medical treatment could be updated at the last minute. As an RME supplier, SPD should have the flexible supply capability to handle...
unpredictable change and emergent cases. Based on the priority of intraday medical treatments, an RHWFS should help SPD manager to make an adaptive workload plan for each reprocessing area. Meanwhile, when multiple machines provide the same function, an RHWFS should adaptively assign orders to these machines with load balancing in mind. It aims to maximize the supply capability and optimize the utilization rate of reprocessing resource.

**R7: Real-time Supply Chain Management (SCM):** Out of stock and delayed supply of ready-to-use RME are two key reasons for clinics to reactively cancel or postpone medical cases. In RHWFS, an RFID-based real-time SCM should be achieved. It aims to trace and transparentize the status of the supply process among multiple stakeholders; track the real-time inventory level in both SPD and clinic secondary inventories; remind SPD distribution technicians to replenish the storage immediately; finally, record the expiration date of each RME and call attention automatically to remove the expired RMEs off the shelf.

4. **Overview of RFID-enabled Real-time SPD Operation Management**

This research is based on the SPD business process in John D. Dingell Medical center, Detroit, MI and selects its major consumption department ‘operation room (OR)’ as an end user. The RMEs life cycle in the simplified SPD-OR business process is shown in Figure 1:

![Figure 1: Simplified SPD-OR Operation Process.](image)

After utilized in OR, the soiled RMEs are collected in a case cart to SPD through an elevator which only transports dirty items. Based on the relative SOP rules, RMEs are decontaminated by some cleaning options, such as hand clean, sonic machine clean and washing machine clean. In the Preparation Area, clean RMEs will be wrapped, packaged, and labeled by a new barcode which shows the basic information of RMEs, such as item ID, expiration date when they should be reprocessed again no matter whether they have been used. Then the sterilization step will be executed for several hours (such as 14 hours for ethylene oxide (ETO) sterilization or 1 hour for steam sterilization) to destroy microorganisms or inanimate objects. All the ready-to-use RMEs will be stored in aseptic SPD inventory. When the OR demands arrive, SPD technician will build a case cart according to the RME list for each OR case. Finally, the prepared case cart will be sent back to OR by another elevator, dedicated to transport ready-to-use items.

The objective of the research is to create a real-time SPD operation management for automatically tracing, monitoring and controlling the operation performance. By integrating RFID and SOA-based workflow system, it
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Aims to achieve ubiquitous connectivity and interoperability between RFID tagged intelligent objects (SPD staff, RMEs, machines), SPD working areas and end users. Zhang et al. innovatively integrated workflow management, multiple agents system and RFID-based automatic data collection technologies into a coherent infrastructure framework for implementing a real-time WFMS in manufacturing [25]. Our research continues to explore the infrastructure framework and deploy it in the healthcare domain by considering the above key requirements in SPD. Figure 2 shows an overview of the proposed infrastructure that demonstrates the three levels of an RFID-enabled real-time SPD operation management system.

- **SPD-floor Management Navigator**: It is the top level and center of the overall system which is composed with the SPD workflow system and some application subsystems, such as SPD planning, SPD inventory management system and other packages, such as customer relationship management (CRM). It supervises the operation management in SPD floor-level, adaptive planning, inventory management and interoperability with other stakeholders. By adopting Service-Oriented Architecture into SPD operation management, three main components are included, i.e. SPD Workload Coordinator as a service requestor, SPD-UDDI to publish and invoke the service provider, Working Area Management Navigator as a service provider. It aims to achieve automatic and real-time management of entire SPD workflows.

- **Working Area Management Navigators**: There are three independent operation management systems serving for the decontamination, preparation, and case cart working areas in SPD. They perform as service providers that take the responsibility to register the functionalities which each working area supplies in SPD-UDDI as Web services, and finally execute each service. Meanwhile, it is also an intelligent-object manager which physically connects all RFID-enabled intelligent objects to control and monitor the real-time information during the reprocessing operation. It aims to achieve service registration and RFID data management.

- **RFID-enabled Intelligent Objects**: They are those physical objects (such as personnel in SPD, RMEs, and SPD machines) attached with RFID tags. Considering the unique physical characteristics of tracking items, active RFID tags are assigned to monitor staffs since passive RFID tags are not good at tracing objects with water or metal. Passive UHF RFID tags with the high accuracy are selected to trace RMEs. Autoclave sensor tags, which could withstand rigorous sterilization processes including ultrasonic cleaning, high pressure liquid sterilization and steam autoclaving are equipped within reprocessing machines for recording the important chemical, biological and temperature indicators.

Figure 2: RFID-enabled Real-time SPD Operation Management System Infrastructure.
5. SOA-based Healthcare Workflow System in SPD

5.1. SOA Reference Architecture for SPD Workflow Management
A Service-Oriented Architecture (SOA) is a set of principles and methodologies for designing and developing software in the form of interoperable services that can be discovered, reused and combined for different purposes. When adopting a workflow system in a dynamic and flexible environment such as healthcare, SOA is a promising solution to meet the requirements of flexibility, interoperability by registering, discovering, and combining reusable tasks as Web services. SOA reference architecture for SPD workflow management is presented Figure 3.

![Figure 3: SOA Reference Architecture for SPD Workflow Management.](image)

5.1.1. SPD Workload Coordinator
SPD workload coordinator schedules and invokes an SPD service based on the status of on-duty resources and priority of demands from end users. A suite of applications are designed to help SPD manager plan workflow adaptively. The main functions are described as follows:

- **Registration of Soiled RMEs**: When soiled RMEs arrive in SPD for reprocessing, the basic information of RMEs, such as item ID, due date of ready-to-use RMEs will be registered in workload order list following the policy ‘first-in-first-out’. The different priority levels of demands from end users will be considered. For example, an emergent order will be processed immediately once it arrives.

- **Grouping of RME Reprocessing Procedures**: In order to optimize the reprocessing procedures, RMEs with similar SOP requirements can be processed together. Thus, this function will convert customers’ orders to reprocessing orders by categorizing RMEs of similar SOPs into one group. If the amount of RMEs from the same group exceeds SPD reprocessing capability, this group could be separated into several subgroups that have similar due date.

- **Resource Management**: This function will trace and display the working status of relative SPD staffs and machines, such as busy or free. It is designed to help SPD manager make a flexible scheduling. If the primary resources are available, undone tasks in the workload list could be immediately executed. Meanwhile, some reprocessing operations without precedence constraints are allowed to be executed in parallel.

- **Workload Planning**: Based on the above information, this function will assign work orders to each service provider and invoke the relative services for reprocessing procedure execution.

5.1.2. SPD services UDDI (SPD-UDDI)
The function of SPD-UDDI is similar to those of standard UDDIs (Universal Description, Discovery and Integration). It serves as a platform-independent framework for describing, discovering, and integrating business services. Five core information types of SPD-UDDI are described as follows:

- **Stakeholder Entity**: working areas, personnel, or machines that offer one or more services in SPD.
- **Reprocessing Service**: a group of web services published by each SPD working area. Each service serves a reprocessing function for certain propose and can be invoked over the Internet.
- **Binding Template**: the information that is necessary to convert working area functions into public Web services and invoke them to implement reprocessing services.
- **Technical Model**: Metadata used to access specifications about a type of service or categorization.
- **Publisher Assertion**: a relationship assertion between two stakeholder entities.

5.1.3. Service Provider
One of functions from each Working Area Management Navigator is responsible for registering the functions from decontamination, preparation, and case cart working areas in SPD-UDDI as Web services. Each provider must decide which services to expose and in which category a service should be listed for each working area. By publishing services’ interface and access information in SPD-UDDI, each task could be executed by a service provider when the relative service is invoked. The conceptual view of service functions provided by each working area in SPD business process is shown in Figure 4:

![Figure 4: Conceptual View of Service Functions Provided By SPD Working Areas.](image)

5.2. A Prototype of Healthcare Workflow System in SPD

Workflow management is used to define and execute the business process through invoking Web services published by service providers. The SPD workflow designer can search necessary services from SPD-UDDI and configure them for a specific reprocessing procedure according to some SOP rules. During execution, the SPD manager could trace and control the status and performance of the running process, and make dynamic business routing based on verification results of a previous task. If one task is not approved, exception control will be performed, such as retrying the same operation. Thus, an SOP rule engine is critical in a healthcare workflow system (HWFS). It aims to assist an SPD manager in rule-based decision making.

The following description about six key components is based on their priorities in an HWFS.

- **SPD Workflow Designer**: It provides a user-friendly graphic interface to design and modify SPD workflows. An SOP expert can drag and drop published services into the design panel and link them together in parallel or sequential patterns to model reprocessing procedures. It aims to provide the workflow definition function in WFMSs.

- **SPD Reprocessing Workflow Engine**: It is the center of the HWFS in SPD. It is used to create and manage the data flow and control flow of a business process, display the workflow status, and record particular aspects of the workflow, such as data provenance.

- **SOP Rule Engine**: It is the intelligent subsystem innovated in the HWFS to assist and guide end users to react correctly given the real-time status of SPD workflows. The SOP requirements and actions that need to be taken when requirements are violated are encoded in terms of rules in an “SOP rule engine”. It can communicate with the SPD reprocessing workflow engine to analyze the complex decision logic when multiple options should be selected based on the instant execution performance.

- **SPD Workflow Monitor**: It records and reports the performance of an SPD workflow. They are historical data which are useful for management, such as the completion time for a task, the stock time of WIP items in one working area.

- **SPD Task Manager**: It shows which tasks are in the queue to be carried out for processing. By selecting a task, the SPD technicians can retrieve a predefined workflow and begin to perform a service.

- **SPD Smart Provenance Manager**: Provenance-based smart reasoning techniques are developed in the smart provenance manager to preventively reduce errors, proactively improve workflow management, and efficiently
produce high-quality ready-to-use RMEs. A smart checker is to ensure that the right RME is performed by the right workflow. A smart verifier is included to verify that each step is complied with SOP requirements. A smart rerun will decide the necessary rerun steps to remedy the nonconforming operations.

5.3. RFID-enabled Automatic Data Collection for Workflow Management in SPD

In order to achieve real-time monitoring and controlling of SPD reprocessing procedures, three types of information should be collected as data sources for the data flows running in the healthcare workflow management system in SPD. They are real-time location and identification information of RMEs and reprocessing resources such as SPD staffs, raw materials, and sensor information of reprocessing environments, such as temperature, pressure. With the development of Auto-ID technologies, multiple types of automatic data collection devices, such as passive and active RFID tags, Wi-Fi tags, autoclave sensor tags, can be deployed to retrieve real-time information automatically.

Passive UHF RFID tags are attached to RMEs to record the information of all locations each RME has passed during a reprocessing procedure. This information aims to trace the cleaning, disinfection, and sterilization tasks for which this identified RME has been processed, which supplies the real-time evidence to verify whether the imperative steps are skipped and reprocessing operations are executed based on the right workflows. The time duration of RMEs in each location can give a clue to reflect the operation time of each task, which is one of the key parameters to ensure the safety quality of RMEs.

Active RFID tags or Wi-Fi tags are attached to reprocessing resources, such as SPD technicians, SPD manager, raw cleaning materials to record the identification and location information. Considering the complexity of reprocessing tasks in SPD, SOP requires that only well-trained SPD technicians can be qualified to reprocess the specific RMEs at certain machines, such as suction machine which is used to remove any debris inside scopes through the water flow. Before starting the tasks, active RFID tags or Wi-Fi tags can automatically retrieve the identification information of on-duty SPD technicians based on their location information and send it to the intelligent-object manager for verifying their qualification status. This helps the SPD manager to effectively control the SPD resources.

Autoclave sensor tags are attached within reprocessing machines, such as a sterilization machine. Multiple types of sensor tags aim to record the chemical, physical, or temperature indicators of reprocessing environment, which are important factors to ensure that each operation is performed under a standard environment.

6. Conclusions and Future Work

One major reason that dramatically impacts patient safety is the use of unclean RMEs delivered from the Sterile Processing Department in healthcare facilities. In this paper, we proposed a solution of RFID-based healthcare workflow management system to improve the performance and quality management of SPD business process. By an enhanced, interdisciplinary understanding of business process management in SPD, seven requirements to ubiquitous control of the SPD business process were summarized. We proposed a three-level infrastructure for RFID-enabled real-time SPD management and discussed the architecture of SOA-based healthcare workflow management systems in detail. An SOP rule engine was innovatively introduced in HWFSs to automatically verify SPD operations. Meanwhile, RFID technologies were used to collect real-time data about the status of SPD business process and indicator value of reprocessing environment. However, several issues need to be investigated further. First, the methodology of compliance check between SPD operations and SOP requirements should be developed based on knowledge management theory. Second, the algorithm of the smart rerun scheme should be designed to refine the optimized routing for exception control. Third, the selection of SPD operations for Web services implementation should be considered as a challenging topic in HWFS development.

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