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Automated hospital pharmacy supply chain and the evaluation of organisational impacts and costs

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ABSTRACT

Supply chain digitalisation equipment's raise concerns for hospital decision-makers, especially regarding the cost-efficiency ratio, usually evaluated through health technologies assessments (HTA) at a national level or by return on investment (ROI) calculations by the hospital finance department. Unfortunately, none of the two methods identifies organisational impacts, nor hidden gains and costs, especially those that are related to the internal reallocation of resources as shows the example of automated dispensing systems (ADS) in the central pharmacy of a French hospital with a posteriori analysis from the hospital perspective. The introduction of the ADS caused some hidden costs or gains, which do not generate any financial flow and which are therefore not valued. When they are valued, as we do in this study by including them in the ROI calculation, the results change dramatically: the profitability of the investment goes from negative to positive. Given the importance of hidden gains and costs related to organisational impacts, they should be included in evaluations.

KEYWORDS

Economic evaluation; health technology assessment; organisational impacts; supply chain; automated dispensing system; hospital

Introduction

Audits of large French hospitals have revealed an underperformance of purchasing and supply chain, specifically for medical supplies which represent more than 40% of a hospital's operating budget (Rakovska and Stratieva 2018). This comes from the critical status of medical supplies in care delivery and the behaviour of all supply chain stakeholders who, in order to prevent inventory shortages, tend to overstock. Overcosts and losses are major (Landry, Beaulieu, and Roy 2016) and therefore there is great potential for improvement through supply chain management (SCM) practices (Nabelsi and Gagnon 2017; Ageron, Benzidia, and Bourlakis 2018). The internal supply chain of hospitals remains the weakest link in hospitals (Landry and Philippe 2004) and the health sector is lagging behind industry as it has not been able to reap the full benefits of SCM due to their slow adoption (McKone-Sweet, Hamilton, and Willis 2005; Toba, Tomasini, and Helio Yang 2008).

This poor performance led hospitals to look for solutions to better manage orders and inventories using the Two-Bin Kanban system (also called empty-full or no-count) or automated dispensing systems (ADS). These dispensing systems raise many questions at the level of health professionals and managers regarding clinical effectiveness, safety, and also costs and economic evaluations, although Health Technologies Assessments (HTA) are already performed at the national level. If the evaluation of the first two dimensions is generally well mastered, the economic one is more problematic. Indeed, ADS, like other medical devices, suffer from a lack of evaluation of their organisational consequences and in particular of their effects on human resources (HR). As the financial resources of hospitals are shrinking, these uncertainties are slowing the adoption of this automated equipment, which is a key element in the digitalisation of the drug supply chain. While drug prescriptions and administration are now most often recorded in computerised patient records, ADS is the missing link in the computerisation of the internal medicine distribution chain. This article aims at demonstrating to what extent taking into account organisational impacts (and more particularly HR impacts) can significantly affect the outcome of economic evaluations and the decision to invest in the intra-hospital supply chain.

Firstly, we remind what the HTA are, how they value automated equipment, and what the intrinsic limits of these assessments are, amongst which is organisational impacts analysis. Secondly, we describe the implementation of two ADS in a French hospital group. Then, we present the results of the study. We highlight three main impacts on the organisation: the physical, the material and the HR impact. Finally, the discussion focuses on the limits of the ROI financial approach and of the HTA economical approach regarding organisational impacts. This ADS case shines a light on the importance to integrate internal data specific to the hospital in the

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evaluation, as each situation has its uniqueness. Moreover, integrating hidden costs and benefits would be beneficial for hospital decision-makers, so that they objectivise the opportunity to deploy this type of equipment and digitise the supply chain.

Literature review

HTAs and their evaluation of ADS

Equipment such as the ADS are generally evaluated like health technologies using the HTA methods. Although they are logistics equipment, they deliver medicines or medical devices that impact both the security of the medication circuit and the patient security, be it directly (for example, with a robot preparing nominative single doses) or indirectly (with central automated management of medicines). They are often categorised as 'health technologies' and are therefore evaluated as such.

HTAs were developed in the 70s and the 80s and have gained an increased recognition since then (Banta 2009; Antioch et al. 2017). They have become a standard policy tool for informing decision-makers who regulate the entry and use of pharmaceuticals, medical devices, and other technologies within health systems (for example, through reimbursement and pricing (Kristensen et al. 2019)). Most Western countries have put in place institutions in charge of HTA (such as NICE in the UK, HAS in France, CADTH in Canada, DACEHTA in Denmark, IQWiG in Germany, etc.), as well as HTA best practices guides.

The best practices are compiled in a guide which is recognised as an international reference in terms of HTA methodologies: the Core Model Version 3.0, issued 25 January 2016 (EUnetHTA Joint Action 2, Work Package 8. HTA Core Model ® Version 3.0'. 2016) by an international experts' network. The key HTA domains are described through the following aspects: 1) health problem and current use of technology, 2) description and technical characteristics of technology, 3) safety, 4) clinical effectiveness, 5) costs and economic evaluation, 6) ethical analysis, 7) organisational aspects, 8) patients and social aspects and 9) legal aspects. It must however be stated that early works in the field, as well as today's researches, tend to focus on efficacy, safety, and cost-effectiveness (Banta 2009; Antioch et al. 2017).

The application of HTA methods to ADS highlights three main results. First, the effectiveness of ADS in reducing dispensing errors is not as clear-cut as it might be expected. According to numerous studies (Lynette et al. 2013; Beard and Smith 2013; Keers et al. 2014) as well as systematic reviews carried out by the Canadian and Australian HTA bodies, the results appear to have 'low' to 'significant' effects (CADTH 2010; Lehnbom et al. 2013), in particular because the studies' methodologies are not comparable, or because the studied equipment are different or non-differentiated. Nevertheless, it appears that globally ADS do contribute to some extent, directly or indirectly, to securing the dispensing process.

Second, with regard to ADS profitability, the conclusions are also not clear-cut despite a number of profitability studies that have been carried out (Risør, Lisby, and Jan 2017), whether they be economic impact studies (CADTH 2010; Beard and Smith 2013; Tsao et al. 2014; Berdot et al. 2016) or calculations of return on investment (ROI) (Glowa and Weber 2009; Bonnabry and Olivia 2020).

Finally, the literature also includes numerous studies which mention other impacts of ADS, such as dispensing duration (Fitzpatrick et al. 2005; Franklin et al. 2008; Lynette et al. 2013), changes in HR usage (Noparatayaporn et al. 2017), stock management (Temple and Ludwig 2010; Beard and Smith 2013; Lehnbom et al. 2013), *etc.*

HTA's limitations

Overall, the ADS evaluation results range from reserved to favourable. However, these studies are not very useful for local decision-makers such as hospital directors and pharmacy managers. Even if HTA has been adopted to provide answers to health-care decision-makers with respect to improving the quality and efficiency of care delivery in a context of limited budgets (Sa'aid and Stewart 2011; Gagnon 2014) and to improve the rationality of the decision-making process, at a local level, actual difficulties to implement HTA are pointed out (Ehlers et al. 2006; Martelli et al. 2013; Gagnon et al. 2014; Radaelli et al. 2014; Martelli et al. 2015):

- Hospitals do not always have the available resources and competences to properly conduct the evaluations;
- They do not necessarily have the right governance model;
- They may lack the methodological level expected to conduct studies on the key HTA domains.

The second limitation is well identified in the literature. Difficulties stem from the fact that HTA evaluation results cannot be easily used for decision-making at the local level (Barasa et al. 2015; Martelli et al. 2015). Today, a consensus seems to form on the use of multi-criteria decision analysis (MCDA) based on multi-attribute value theory (Poulin et al. 2013; Radaelli et al. 2014; Angelis and Kanavos 2017; Antioch et al. 2017; Lasalvia et al. 2019) to help decision-making. This was initiated by the NICE during the 2010 s' (Antioch et al. 2017). As a matter of fact, the complexity resides in that health-care organisations are often expected to

pursue a number of different goals (quality of treatment, economic efficiency, flexibility of activities, development of knowledge, efficient management, political legitimacy, *etc.*). It is therefore especially difficult for a local hospital decision-maker to make a decision based on a national or international HTA analysis, as robust as it may be. This was clearly underlined by Kristensen et al. (2019):

> HTA, encompassing evidence synthesis, may be viewed as informing evidence-based decision-making – two related but distinct concepts. The process of rigorous review and synthesis of scientific evidence focuses on assessing the relative benefits, harms, and costs of healthcare technologies using sound analytic judgments. Evidence-based decision-making, in most cases, explicitly or implicitly incorporates other considerations (e.g. affordability, ethical issues, feasibility, and acceptability) that may require mechanisms of contextualization of assessment results, such as deliberative processes, to support them.

The MCDA method that was developed with the creation of multi-variable Mini-HTA seems to be a relevant tool at the local decision-making level (Sampietro-Colom et al. 2012). It could furthermore reconcile the hospital procurement department with the HTA which analysis methods are sometimes divergent (Callea et al. 2017; Miller et al. 2019).

The third limitation deals with the transposability of HTA results:

- Firstly, the study design of HTA is commonly based on the paradigm of the environment and the technology's stability. This is often not the case (Douma et al. 2007). It seems indeed necessary to take into account the technology dynamics; attention should be paid to the operationalisation of the phases of development, implementation and integration (for example, the 'learning curve' in HTAs).
- Moreover, as mentioned earlier, HTAs are historically focused on three domains (efficacy, safety, and cost-effectiveness). Yet, the implementation of a technology is often dependent on the operators in place, and more broadly, on the available resources and competences, as the resource-based view theory underlines (Barney 1991, 2001). Those are not integrated into the HTA. Furthermore, there are important differences amongst the hospitals within the health system. These differences affect the prioritisation of a technology's attributes. This could result in different conclusions with regard to the use of this technology in each hospital (Mitchell et al. 2010).
- Drawing on that, HTAs do not take into account organisational and economic impacts of innovations (Drummond, Griffin, and Tarricone 2009; Craig et al. 2015; Facey et al. 2015; Tarricone, Torbica, and Drummond 2017a). This aspect of evaluation appears in the best practices of Core Model version 3, but it is not used by the HTA bodies. They are all aware of that and they have made this a priority objective for the future (Tarricone, Torbica, and Drummond 2017b; Tarricone et al. 2017). HAS especially integrated it in its 2019–2024 work program (Haute Autorité de Santé 2018).

Taking these limitations into account, hospital directors and pharmacy managers in charge of pharmacy automation reduce their HTA to the strictly financial dimension by calculating an ROI. This conveys the advantage of identifying all the direct and indirect costs of this equipment. It integrates the investment cost of the ADS, but also indirect costs such as additional equipment or maintenance, as well as the savings which are made on medicines' stocks and staff. However, this approach does not provide them with a global vision of the multiple impacts of automation, both in its upstream and downstream phase. In particular, it does not take into account the complex transformation of the organisation of services (specifically the pharmacy and health-care services) because the financial method to calculate an ROI is to use cash flow – the actual amount of cash moving in and out of an organisation over a period of time.

These issues are highlighted in the study we conducted on the implementation of two ADS robots in the central pharmacy of a large non-university hospital in France.

Methods

Design and setting

This study is taking place in one of the largest non-university hospitals in France. With a capacity of 2,500 beds and room for 300 day-patients, 70,000 patients and 130,000 emergencies were treated in 2016, the year before the conduct of the study. The hospital is the product of a nine-establishments merger between medical institutions in a fixed geographical radius, which included seven short-stay care (medicine, surgery, obstetrics) institutions for a population of over 400,000 inhabitants. The hospital disposes of two centralised pharmacies divided into five satellite pharmacies corresponding to the different hospital sites. The study is carried out on the largest of these entities, which manages nearly 1,500 medications and employs the equivalent of 47 full-time employees.

Intervention

The study was carried out *a posteriori* in June 2017, 6 months after the installation of two global dispensing robots.

Data collection

The study focused on the dispensing phase, from the care unit order to the sealing of the dispensing boxes before they are sent to the wards. Particular attention was given to measuring the changes in processes and costs before and after the implementation of the robots. Hence, two categories of data were collected for this study: data describing the dispensing system of medicines and data related to the ADS implementation costs.

The modelling of the dispensing process before and after implementation of the ADS was central to understanding and identifying organisational and financial impacts. We used process mapping method to conduct a two-hour group interview with representatives of the different professions involved in the distribution process: pharmacists, pharmacy assistants and healthcare executives from the pharmacy, as well as nurses, the storekeeper, the purchase order manager and the system information manager. In order to take into account the specific organisation of each medical speciality, three nurses, respectively, belonging to a medical department, a surgical department and a psychiatric department, were present. The interview was conducted on a voluntary basis.

Semi-structured individual interviews with 27 professionals from departments involved in the implementation or affected by the robot and also from the ADS supplier were also conducted to complete and document the process (See Table 1 for details): pharmacy department, hospitalisation wards, logistics department, information systems department, management control department, administrative and financial department, and hospital maintenance department. Interviews lasted between 30 minutes and 90 minutes.

The interview guide dealt with two main topics: the course of the project and the routine operation of the robot. Concerning the project, the role of the interviewee as well as the time spent during the different stages of the project was described. Difficulties encountered and solutions found were also discussed. Finally, the resources used and cost data were requested. Regarding the operation of the robot, the interview addressed its impact on four dimensions: work organisation (role distribution, increase or decrease of the duration of certain tasks and processes, training needs, etc.); the architecture of the department's premises; the materials used (trolleys, etc.) and the pharmacy activities carried out (creation of new activities of clinical pharmacy in medical and surgical departments).

Finally, the global opinion on the added-value or disadvantages brought by the robot from the point of view of the pharmacy department, the clinical departments, the patients and the hospital was requested.

Although there was no exhaustive account of the time spent by the various employees who contributed to the project management process, an estimate was provided by the project managers and subsequently validated by the concerned individuals. The administrative, technical and pharmaceutical teams had also documented the ADS implementation process by quantifying the time allocated to project management and implementation-related activities. These elements were supplemented by the collection of a large amount of on-site data: pharmacy and establishment activity statistics, technical manuals for equipment, installation plans, personnel worksheets, project management reports, management analyses from accounting and management control.

The time spent by pharmacy assistants on care unit dispensing was measured at three points in time, each lasting 1 week: prior to, 2 and 6 months after the ADS implementation. Data were collected on preparation time for wards allocation renewal, excluding preparation of urgent requests, which are of a more random nature. The analysis also distinguished dispensing time from time

Table 1. List of interviewees and breakdown by domain.

Pharmacy and clinical services	Administrative and support services	ADS Robot manufacturer
Pharmacist – project manager	Hospital Managing Director	Strategic Accounts & Business Development Director
Pharmacist- co-project manager	Secretary-General	Director, Regulatory Affairs & Health Economics
Pharmacist – Head of Division	Director of Controlling	International Marketing Director dispensing
Head nurse of the pharmacy service	Administrative and Financial Director	Technician
Pharmacist – Quality Manager	Head of Controlling	Technician in charge of hospital staff training
Pharmacist	Director of Billing	
Pharmacy technicians (2)	Technical Engineering Manager	
Pharmacy Storekeeper (2)	Buyer	
Nursing staff: – 2 general practice nurses – 1 psychiatric nurse – 1 outpatient surgical nurse	Analyst in the information systems department	

lost due to interruption (handling of other tasks, robot breakdown), as well as from the time needed for the final validation of the unit medication orders.

The pharmacy staff conducted a study on the number of dispensing errors by care unit orders, before and after implementation of the ADS. In this study, the errors of dispensing were monitored every day during the week of the study, at three time periods: December 2016, February and June 2017. It involved comparing several wards' department orders with the actual content of the dispensing box prepared by the assistants. The measured values do not necessarily represent common practices because of the Hawthorne effect. However, this bias has no impact on the time series analysis, since the data collection protocol was the same over the three observation periods.

Another study conducted in the pharmacy quantified the number of medicines dispensed, the dispensing time and the number of dispensing errors. Care units were also asked to return unused medication 1 month before and after implementation to assess whether the robot had had an impact on reducing returns and thus better met services' expectations.

Costs data were provided by the financial department of the hospital. The costs of human resources (time spent, and FTE saved) used in the study is the average cost weighted by job position. It was thus calculated by the financial department.

The ADS is depreciated over a period of 15 years, in accordance with standard accounting practice, like the other equipment related to the ADS, with the exception of small equipment for which the depreciation is calculated over a 10-year period. Therefore, the present value of the estimated future cash flow has been determined using the French 15-year bond interest rate as of February 2017.

Results

The study identified three main impacts on the organisation, which are related to physical, material (the medicines) and HR. Each of these categories includes changes in the work structure and organisation that result in both operating costs and savings.

Impacts on physical resources

In order to prepare for the installation of the ADS, the hospital arranged for construction works to be carried out, a large part of which (air conditioning, painting, changing the windows, *etc*.) satisfied the need to bring the old facilities up to the current standards. These works were not due to the specific installation of the ADS. Only the electrical works were directly related to that, as the installation of the ADS required a specific electrical system, which represented 14% of the total installation cost.

The hospital acquired various additional items of equipment related to the installation of the ADS. In particular, it invested in additional shelves for the storage of medical products that could not be loaded into the ADS, in carts to ease the handling of the dispensing boxes and in blank cardboard boxes used to return medications into the robot stock.

Finally, the maintenance costs of the ADS and of the IT interface with the pharmacy software have also been included into the estimate of financial impacts.

The installation of this ADS and therefore the reorganisation of the stock has freed substantial floor surface in the pharmacy. The resulting 78.95 square metres were used to instal two new refrigerated storage rooms. It may therefore be considered that the hospital made savings relative to the newly available surface following the ADS installation.

Impacts on efficiency and learning curve: the evolution of dispensing errors and stocks value

The results (Table 2) show that the rate of 'non-compliant' order lines has progressively diminished over the months to stabilise at 0.4% in June 2017 (with the ADS), as compared to 1.7% in December 2016 (before the ADS). With regards to the number of care units concerned, the rate of 'non-compliant' units amounted to 0.2% in June 2017, as compared to 0.6% in December 2016. This evolution clearly underlines the notion of learning curve, which is unfortunately poorly taken into account in HTA (Drummond, Griffin, and Tarricone 2009; Tarricone, Tarricone et al. 2017).

> *The introduction of the robot forced us to adjust stocks and allocations. A step of validation of the orders in relation to the allocations has been added which allows a better control and more quality (verbatim from an interviewee Pharmacist).*

Nevertheless, quantitative errors remain. Human intervention in the manual picking process (required for products which are stored outside the ADS) and in the dispensing of unit doses for specific medications (only part of medication box dispensed by the ADS is allocated to the order and any remaining medication is put back in the ADS stock) explain these quantitative errors.

> *The most time-consuming task since the robot introduction is to enter on computer the opened medicine packages returning from the services. You have to unpack them before repacking them with white (generic) packages; you then have to enter the information (expiry date, batch number, etc . . .) in the computer system to edit the right label so that the stock is correct and finally reintegrate this package in the robot. We have to think about favouring complete packages, otherwise we spend*

Table 2. Number of dispensing errors in preparing the ward's requests, before and after robot implementation.

	Lines					Units				
Period of data collection	Dispensing lines checked (Nb)	Compliant (Nb, ratio)		Non compliant (Nb, ratio)		Dispensing units checked (Nb)	Compliant (Nb, ratio)		Non compliant (Nb, ratio)	
Dec, 2016	1,609	1,581	98.3%	28	1.7%	50,818	50,512	99.4%	306	0.6%
Feb, 2017	1,496	1,483	99.1%	13	0.9%	48,734	48,353	99.2%	381	0.8%
June, 2017	1,747	1,740	99.6%	7	0.4%	47,2306	47,230	99.8%	76	0.2%

too much time on it. (verbatim from a Pharmacy technician)

Finally, the fewer returns we receive from the services, the better the stocks are managed; we should ask them to return only exceptional drugs: those that are not in their weekly supply and that they will not have the opportunity to use; we should train the care units on this subject again. (verbatim from a Pharmacist project manager)

After the introduction of the ADS, a decrease in the stock value of €61,000 between 2016 and 2017 (annual basis) was observed. Considering that hospital activities increased by 2.91% during that period, the gain in the stock value may be estimated at €176,000 i.e. a 4.3% reduction, when the effect of the variation in activity is balanced out (all else being equal).

Considering the value of the returned medications from the care units (observed over 4 months and extrapolated over a one-year period) and discounting the growth of pharmacy activity, this study shows a reduction in returns of more than €18,000, i.e. a 2.6% reduction following the ADS implementation. Therefore, this tends to confirm the existence of a better management of global drugs allocations to the wards.

Impacts on HR and competencies: the hospital staff

To take the analysis one step further, we have identified the impacts of the two ADS on HR, during the preparation and implementation and the operation of the new automated process.

In order to prepare for the installation of the ADS, the hospital staff organised meetings and involved employees. A total of 1,090 working hours were dedicated to preparing for the installation of the ADS, including 144 hours (13%) of multidisciplinary meetings, and 946 hours (87%) in the pharmacy department alone where most of the time was spent loading the medications into the ADS.

The ADS implementation required the creation of an IT interface to connect the robot with the pharmacy medication management software and to allow for the exchange of information. The IT department was largely involved in the preparation and implementation of the robot in order to ensure that the new stock management and dispensing system would be functional from the start. This took an estimated 413 hours, essentially for the configuration, qualification and deployment of the new versions of the pharmaceutical software, the department web order modules and the financial software.

The hospital also organised a number of training and information sessions on the ADS and on its usage. Additionally, a total of 105 hours of training were provided by the robots' supplier.

The effects of automation of the process on working hours must also be taken into account. Looking into the activity of every pharmacy assistant involved in central pharmacy dispensing activities, a 28% time-saving was discovered (Table 3).

Note: the increase of 122% of validation time is due to the introduction of an additional validation step, improving the dispensing efficiency and quality. However, this step was easily integrated by the team as this difference was absorbed by June.

This represents the equivalent of 1.25 FTE assistants: Although there has been no reduction in the number of pharmacy employees, the time freed up through the ADS has made it possible to absorb an increase in activities and to perform other tasks aiming at improving the quality management and safety of the drug-dispensing system.

The robot has allowed us to rethink the organisation of the service and to improve other things as well. For example, now we have access to the data on the PC and it is easier to make a second validation of the order (on quantities this time). (verbatim form a Pharmacist project manager)

The management of expired products is made easier: you can request a forced removal of expired products. The robot blocks the dispensing of medicines that will expire within 30 days. (verbatim from a Pharmacy technician)

Discussion

The objective of this case study was not to realise an HTA, as this type of analysis is already available in the literature. The aim was to allow the hospital director to identify the organisational and financial impacts of this equipment and to help him decide whether it would be worth deploying at a larger scale. As noted by (Batson et al. 2020), there is no robust body of

Table 3. Evolution of dispensing time.

	Before implementation	After implementation			
	Average time Dec 16 (min)	Average time Feb 17 (min)	Discrepancy Feb 17/ Dec 16 (%)	Average time June 17 (min)	Discrepancy June 17/ Dec 16 (%)
Dispensing time	259.8	146.8	−43%	252.5	−3%
Software validation time	32.8	76.4	133%	39.2	20%
Interruption time	51.6	21.2	−59%	35.6	−31%
TOTAL time	344.2	244.4	−29%	327.3	−5%
Numbre of lines	456.6	479	5%	600.2	31%
Total time per line	0.75	0.51	−32%	0.55	−28%
of which dispening time per line	0.57	0.31	−46%	0.42	−26%
of which validation time per line	0.07	0.16	122%	0.07	−9%
of which dispening and validation time per line	0.64	0.47	−27%	0.49	−24%

literature to support evidence-based recommendations regarding the clinical or economic benefits of ADS.

There are different ways of assessing the impact of an investment, depending on whether one considers the income and expenses actually recorded in the accounts or whether one considers the cash flow generated or the financial structure of the establishment (balance sheet). In this case, the first calculation generally performed is that of cash flow, which also allows ROI to be calculated. It should be remembered that according to international financial standards, ROI only includes external (i.e. 'observed') economic flows, whereas several studies mention ROI but use methodologies that do not correspond to this definition (Glowa and Weber 2009; Berdot et al. 2016; Bonnabry and Olivia 2020). Calculations made in these studies also include internal economic flows, which are normally not taken into account in a traditional ROI (these flows should be normally outside of the scope of a standard ROI calculation). In other words, the internal flows are hidden in a standard financial ROI calculation. The term 'hidden' refers both to what does not appear in the input-output black box (Martinet and Savall 1978) and to the allocation (or reallocation) of internal organisation resources (such as job shifts or time spent on staff training).

In this case, the hidden costs (and profits) mainly relate to the use of HR. The automation of certain tasks impacts pharmacy processes and preparation time significantly (almost 30% reduction in the case study). However, these benefits are not achieved through staff reductions, but through redeployment of employees to new positions as it is reported in other studies (Berdot et al. 2019; Bonnabry and Olivia 2020). The hospital chose to keep its staff because of the growth of its structure and activities. It also aimed at improving the quality processes of the pharmacy and at implementing other dispensing system (secured cabinets). Nevertheless, it achieved savings, because otherwise it would have had to recruit additional staff to support these activities. Thus, depending on the workload saturation, two scenarios are possible. In some hospitals, the shortage of staff results in an overload of work; the productivity gains are then directly absorbed into the activity and simply reduce the overload. In other hospitals, these gains give the opportunity to invest in new missions or to launch new projects.

Still, these benefits, which do not generate 'observed' financial flows, could be taken into account, if the objective is to reflect the reality of the impacts of this kind of equipment, regardless the hospitals' political and organisational choices in terms of redeployment or redundancies. In the same logic, but with an opposite effect, the preparatory phase prior to the ADS deployment certainly contains hidden costs due to the many hours that were devoted by the establishment's teams in the pharmacy and other departments for its implementation (meeting, training, updating the software, *etc.*) or in the following years. These hours undoubtedly constitute a hidden cost insofar as these staff members are employees of the establishment; there was therefore no observed difference in financial flows. We were also able to observe an increase in time spent (thus a hidden cost) by the invoicing service due to the duplication of medication orders to the same suppliers (one for the robot stock and one for the external stock to secure the right medicine allocation during the implementation of the robot). In addition, identifying this organisational impact and valuing it (estimated at €25,000) allowed the hospital to improve its organisation and thus to optimise its profits.

> *With the installation of the robot, we have duplicated the entire control circuit: on the one hand there is what happens with the "robot" stock and on the other hand what happens with the "outside the robot' stock. Thus, for the same supplier, there are 2 orders, 2 invoices, 2 settlements and 2 treasuries. Moreover, the invoicing department is overwhelmed. (verbatim from a Pharmacist project manager)*

Based on these two alternative methodologies (standard ROI versus ROI including hidden gains and cost), the results obtained in terms of economic impact change radically. Table 4 summarises not only the positive and negative cash flow observed but also the

Table 4. Description and valuation of impacts depending on the calculation method.

	Impact identified	Cash flow	Cash flow including hidden costs and gains, all else being equal (in Euros over a 15 years period)
Preparatory phase			
Pharmacy infrastructure	Subcontracting of lectricity adaptation works, mandatory for robots installation	−30.041	−30.041
	Hospital staff hours dedicated to construction and repair works, related to ADS implementation	–	−2.157
	Subcontracting for dismantling the old equipment	−6.000	−6.000
	ADS supplier fees for its support during the implementation	−2.304	−2.304
IT	Purchase of software licence for robots and internal information system interface	−13.968	−13.968
	Hospital staff hours dedicated to implementing the IT interface	–	−18.763
HR for project preparatory phase	Hospital staff hours spent in interdisciplinary project preparation meetings	-	−5.416
	Hospital pharmacy staff hours dedicated to the update of the pharmacy procedures and booklet	–	−4.394
	Hospital pharmacy staff hours dedicated to moving the stock, loading the ADS and testing it	–	−24.979
Staff training	Hospital staff hours dedicated to training for ADS usage	–	−3.897
Robot and equipements			
ADS and maintenance	Purchase of ADS and belt conveyor	−186.915	−186.915
	Purchase of prolog (automatic loader)	−27.000	−27.000
	Subscription for annual software maintenance performed by the ADS supplier	−19.440	−19.440
	Hospital pharmacy staff hours dedicated to the annual software update	–	−5.565
	Subscription for technical maintenanceperformed by the ADS supplier	−96.000	−96.000
Additional equipment	Purchase of additional storage equipment	−4.264	−4.264
Implementation and operation phase			
Small consumable products	Purchase of blank boxes for medecines	−38.023	−38.023
	Purchase of small office consumable	−8.132	−8.132
Stocks	Stocks variation	61.000	175.568
	Storage space gain in the hospital pharmacy	–	80.526
HR	Reduction in hospital pharmacy staff hours dedicated to dispensing	–	708.750
	Increase of hospital staff hours dedicated to billing	–	−24.290
TOTAL		−371.087	443.296
Break-even point 4 years		over	15 years

alternative method including hidden costs that are usually not considered from an ROI perspective.

Notes: The scope chosen for estimating the cost associated to each impact corresponds to the specific ADS implementation in this specific hospital.

The cash flow calculation shows a total cost of €-371,000 observed over the 15-year amortisation period of the ADS. Nevertheless, when hidden costs and benefits are considered, the hospital would realise savings estimated to €443,296 over the 15-year depreciation period, with an ROI observed in the fourth year (Figure 1).

The Net Present Value (NPV) of this investment at a discount rate of 1.48% equals €387,853, with the same time span.

These results show that taking into account certain costs or benefits that do not appear in the calculation

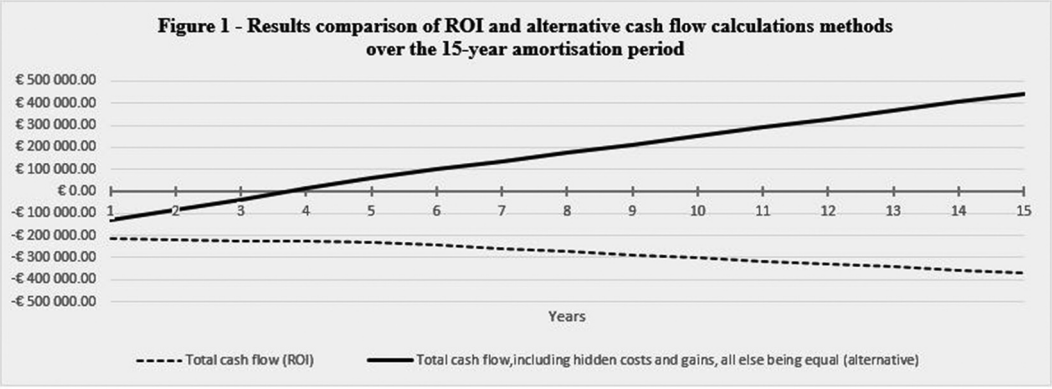

Figure 1. Results comparison of ROI and alternative cash flow calculation methods over the 15-year amortisation period. (Figure from the authors).

of standard ROI can profoundly change decision-making. However, there are two limitations that could be amended by further work.

First of all, the amortisation period and discount rate used in the NPV calculation are subject to debate, as in all NPV calculations. Each hospital itself determines the amortisation period it considers to be fair, while remaining consistent with financial standards. However, practices vary widely. A 15-year period was chosen by the hospital in this study, but other publications use 8-year periods (Berdot et al. 2019; Bonnabry and Olivia 2020). A shorter period may seem judicious (Berdot et al. 2019) because of technological and regulatory changes that can lead to premature obsolescence of the system. This work could therefore be supplemented by a sensitivity analysis on the amortisation period and the interest rate. Finally, organisational impacts have not been identified in a systematic way because there is no unanimously recognised frame of reference (Ciani et al. 2015; Fuchs et al. 2016), aside from a few attempts that are poorly methodologically supported (Roussel et al. 2016). The list of elements to be taken into account in the calculation of hidden costs could probably be extended to include other items: adverse drug events (Orlikowski 2000; Bonnabry and Olivia 2020), reduced salary costs because of task transfer, but also more intangible effects such as user satisfaction, working atmosphere, or absenteeism. Added-value of robotisation as risk-mitigation strategy in time of epidemics such as COVID-19 could even be considered, since ADS require less manpower to operate therefore guaranteeing operations even if some of the staff is on sick leave, in quarantine or reallocated to other tasks. These effects are a source of hospital efficiency that today goes largely unnoticed and raise the challenge of defining the relevant scope of analysis. Therefore, it seems necessary, as the HTA bodies underline it, to develop a systematic screening method based on a recognised corpus. This subject is currently being explored by HTA bodies and researchers. When further developed, it might benefit to the evaluations and position-taking of local decision-makers and thus contribute to improve evidence-based decision-making in the healthcare supply chain.

Conclusion

This research highlights the importance of evaluation in making the decision to invest in equipment similar to ADS. Be it through the HTA methods or through the financial calculation of an ROI, organisational impacts (and in this case, the impact on HR) are not or only partially quantified. Technology causes organisational modifications for which hidden costs or benefits might exist without even being identified nor taken into account.

Therefore, this raises the question of which methodology should be chosen when considering the particular relationship that links technology with organisations. Indeed, as shown by the work of the socio-technical school of thought in the 1950s (Emery and Trist 1960) and subsequent research on the Actor-Network theory (Akrich 1987; Callon 1986) as well as the structuration theory (Orlikowski 2000), the effects of the introduction of a new technology are conditioned by the social and organisational system in which it is embedded. In other words, technology development is in itself a social process influenced by the organisations generating it (DACEHTA 2008). The actual uses and effects of the machines very often differ from the expected uses. They depend on the adoption and on the appropriation processes specific to each structure (Bentahar and Benzidia 2019). Logistics practices are therefore impacted as they often take the form of an amalgamation of resources (human, technological, procedural) (Landry, Beaulieu, and Roy 2016) and constitute organisational routines. It is even more true in hospitals because the health-care sector seems to be rather idiosyncratic when implementing logistics best practices (Guimarães et al. 2013).

Of course, health-care decision-makers ask for one unique organisational model which could capture 'everything'. However, the organisational analysis which can be used independently of organisations and problems, and give the overall picture, does not exist. Organisational analyses cannot be introduced like recipes. They must go beyond the strict clinical and economical approach and be adapted to the individual cases and problems (DACEHTA 2008).

In this case study, the cost is contingent to the existing internal organisation of each establishment and in particular to the choices that were made when allocating or reallocating the personnel to certain activities. This choice itself depends on the strategical and clinical project of the hospital, its quality and security objectives, on the one hand, and its observed and aimed productivity levels, on the other hand. This result can be of great interest in a labour-intensive industry like health-care industry, where the automation potential of logistic activities is high.

Unlike national HTA bodies, hospital-based HTA evaluations may integrate local data into their guidelines and reports. Local data can not only fill gaps in the published evidence, but it can also improve the generalisability of evidence to the local setting (Mitchell et al. 2010). Should the solution come from health economists or from supply chain managers? In any case, it seems necessary to more systematically and more explicitly identify and value the gains (and costs) hidden by reallocating internal resources as also suggested by Batson et al. (2020). This would increase the speed of the transformation of logistics practices and the performance achieved in hospitals where a lot has to be done to explore and understand the value of digitalisation and

its impact on the organisation of flows, quality of service, working conditions, and skills acquisition and development for stakeholders (Ageron et al. 2019). In any case, we hope that this article will contribute to advancing the reflexions around investments in hospitals' supply chain, be them in ADS or other digital equipment.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Ageron, B., S. Benzidia, and M. Bourlakis. 2018. "Healthcare Logistics and Supply Chain – Issues and Future Challenges." *Supply Chain Forum: An International Journal* 19 (1): 1–3. doi:10.1080/16258312.2018.1433353.

Ageron, B., S. Benzidia, O. Bentahar, and J. Husson. 2019. "Investigating Automation and AGV in Healthcare Logistics: A Case Study Based Approach." *International Journal of Logistics Research and Applications* 22 (3): 273–293. doi:10.1080/13675567.2018.1518414.

Akrich, M. 1987. "Comment Décrire Les Objets Techniques? [In French]." *Techniques & Culture, No* 9: 49–64.

Angelis, A., and P. Kanavos. 2017. "Multiple Criteria Decision Analysis (MCDA) for Evaluating New Medicines in Health Technology Assessment and Beyond: The Advance Value Framework." *Social Science & Medicine* 188 (September): 137–156. doi:10.1016/j.socscimed.2017.06.024.

Antioch, K. M., M. F. Drummond, L. W. Niessen, and H. Vondeling. 2017. "International Lessons in New Methods for Grading and Integrating Cost Effectiveness Evidence into Clinical Practice Guidelines." *Cost Effectiveness and Resource Allocation* 15 (1): 1. doi:10.1186/s12962-017-0063-x.

Banta, D. 2009. "What Is Technology Assessment?" *International Journal of Technology Assessment in Health Care* 25 (S1): 7–9. doi:10.1017/S0266462309090333.

Barasa, E. W., S. Molyneux, M. English, and S. Cleary. 2015. "Setting Healthcare Priorities in Hospitals: A Review of Empirical Studies." *Health Policy and Planning* 30 (3): 386–396. doi:10.1093/heapol/czu010.

Barney, J. 1991. "Firm Resources and Sustained Competitive Advantage." *Journal of Management* 17 (1): 99–120. doi:10.1177/014920639101700108.

Barney, J. 2001. "Resource-Based Theories of Competitive Advantage: A Ten-Year Retrospective on the Resource-Based View." *Journal of Management* 27 (6): 643–650. doi:10.1177/014920630102700602.

Batson, S., A. Herranz, N. Rohrbacj, M. Canobbio, S. A. Mitchell, and P. Bonnabry. 2020."Automation of In-Hospital Pharmacy Dispensing: A Systematic Review." *European Journal of Hospital Pharmacy*, April. doi:10.1136/ejhpharm-2019-002081.

Beard, R. J., and P. Smith. 2013. "Integrated Electronic Prescribing and Robotic Dispensing: A Case Study." *SpringerPlus* 2 (1): 295. doi:10.1186/2193-1801-2-295.

Bentahar, O., and S. Benzidia. 2019. *Supply Chain Management De La Santé*. 1st ed. Caen : Editions EMS.

Berdot, S., V. Korb-Savoldelli, E. Jaccoulet, V. Zaugg, P. Prognon, L. M. M. Lê, and B. Sabatier. 2019. "A Centralized Automated-Dispensing System in A French Teaching Hospital: Return on Investment and Quality Improvement." *International Journal for Quality in Health Care* 31 (3): 219–224. doi:10.1093/intqhc/mzy152.

Berdot, S., V. Savoldelli, V. Zaugg, E. Jaccoulet, P. Prognon, L. Minh, M. Lê, and B. Sabatier. 2016. "Return on Investment after Implementation of a Centralized Automated Storage System in a Hospital Pharmacy." *Journal of Pharmacy and Pharmacology* 4: 10.

Bonnabry, P., and F. Olivia. 2020. "Return on Investment: A Practical Calculation Tool to Convince Your Institution." *European Journal of Hospital Pharmacy* 27 (2): 111–113. doi:10.1136/ejhpharm-2018-001733.

CADTH. 2010. "Technologies to Reduce Errors in Dispensing and Administration of Medication in Hospitals: Clinical and Economic Analyses." *CADTH Technology Overviews* 1 (3): 1-5.

Callea, G., P. Armeni, M. Marsilio, C. Jommi, and R. Tarricone. 2017. "The Impact of HTA and Procurement Practices on the Selection and Prices of Medical Devices." *Social Science & Medicine* 174 (February): 89–95. doi:10.1016/j.socscimed.2016.11.038.

Callon, M. 1986."La Domestication Des Coquilles Saint-Jacques et Des Marins-Pêcheurs Dans La Baie de Saint-Brieuc [in French]". *Eléments Pour Une Sociologie de La Traduction. L'année Sociologique*, 169–208.

Ciani, O., B. Wilcher, C. R. Blankart, M. Hatz, V. P. Rupel, R. S. Erker, Y. Varabyova et al. 2015. Health technology assessment of medical devices: a survey of non-European union agencies. *International Journal of Technology Assessment in Health Care* 31 (3): 154–165.

Craig, J. A., L. Carr, J. Hutton, J. Glanville, C. P. Iglesias, and A. J. Sims. 2015. "A Review of the Economic Tools for Assessing New Medical Devices." *Applied Health Economics and Health Policy* 13 (1): 15–27. doi:10.1007/s40258-014-0123-8.

DACEHTA. 2008. "Health Technology Assessment Handbook". Finn Børlum Kristensen and Helga Sigmund. https://www.sst.dk/en/publications/2008/health-technology-assessment-handbook

Haute Autorité de Santé. 2018. "Projet Stratégique 2019-2024". https://www.has-sante.fr/upload/docs/application/pdf/2018-11/projet_strategique_2019-2024.pdf

Douma, K. F. L., K. Karsenberg, M. J. Hummel, M. Bueno-de-mesquita, and H. W. H. Van. 2007. "Methodology of Constructive Technology Assessment in Health Care." *International Journal of Technology Assessment in Health Care* 23 (2): 162–168. doi:10.1017/S0266462307070262.

Drummond, M., A. Griffin, and R. Tarricone. 2009. "Economic Evaluation for Devices and Drugs - Same or Different?" *Value in Health* 12 (4): 402–406. doi:10.1111/j.1524-4733.2008.00476_1.x.

Ehlers, L., M. Vestergaard, K. Kidholm, B. Bonnevie, P. H. Pedersen, T. Jørgensen, M. F. Jensen, F. B. Kristensen, and K. Mette. 2006. "Doing Mini–Health Technology Assessments in Hospitals: A New Concept of Decision Support in Health Care?" *International Journal of Technology Assessment in Health Care* 22 (3): 295–301. doi:10.1017/S0266462306051178.

Emery, F. E., and E. L. Trist. 1960. "Socio-Technical Systems." *Management Science Models and Techniques, No* 2: 83–97.

'EUnetHTA Joint Action 2, Work Package 8. HTA Core Model ® Version 3.0.' 2016. "EUnetHTA". www.htacoremodel.info/BrowseModel.aspx

Facey, K., C. Henshall, L. Sampietro-Colom, and S. Thomas. 2015. "Improving the Efficiency of Evidence Production for Health Technology Assessment." *International Journal of Technology Assessment in Health Care* 31 (4): 201–206. doi:10.1017/S0266462315000355.

Fitzpatrick, R., P. Cooke, C. Southall, K. Kauldhar, and P. Waters. 2005. "Evaluation of an Automated Dispensing System in a Hospital Pharmacy Dispensary." *The Pharmaceutical Journal* 274 (June): 763–765.

Franklin, B. D., K. O. Grady, L. Voncina, J. Popoola, and A. Jacklin. 2008. "An Evaluation of Two Automated Dispensing Machines in UK Hospital Pharmacy." *International Journal of Pharmacy Practice* 16 (1): 47–53. doi:10.1211/ijpp.16.1.0009.

Fuchs, S., B. Olberg, D. Panteli, and R. Busse. 2016. Health technology assessment of medical devices in Europe: processes, practices, and methods. *International Journal of Technology Assessment in Health Care* 32 (4): 246–255.

Gagnon, M.-P. 2014. "Hospital-Based Health Technology Assessment: Developments to Date." *PharmacoEconomics* 32 (9): 819–824. doi:10.1007/s40273-014-0185-3.

Gagnon, M.-P., M. Desmartis, T. Poder, and W. Witteman. 2014. "Effects and Repercussions of Local/Hospital-Based Health Technology Assessment (HTA): A Systematic Review." *Systematic Reviews* 3 (1): 129. doi:10.1186/2046-4053-3-129.

Glowa, T. W., and R. J. Weber. 2009. "Establishing a Plan for Central Pharmacy Automation." *Hospital Pharmacy* 44 (5): 431–438. doi:10.1310/hpj4405-431.

Guimarães, M., J. Cristina, C. de Carvalho, and A. Maia. 2013. "Vendor Managed Inventory (VMI): Evidences from Lean Deployment in Healthcare." *Strategic Outsourcing: An International Journal* 6 (1): 8–24. doi:10.1108/17538291311316045.

Keers, R. N., S. D. Williams, J. Cooke, T. Walsh, and D. M. Ashcroft. 2014. "Impact of Interventions Designed to Reduce Medication Administration Errors in Hospitals:

A Systematic Review." *Drug Safety* 37 (5): 317–332. doi:10.1007/s40264-014-0152-0.

Kristensen, F. B., D. Husereau, M. Huić, M. Drummond, M. L. Berger, K. Bond, F. Augustovski, et al. 2019. "Identifying the Need for Good Practices in Health Technology Assessment: Summary of the ISPOR HTA Council Working Group Report on Good Practices in HTA." *Value in Health* 22 (1): 13–20. doi:10.1016/j.jval.2018.08.010.

Landry, S., M. Beaulieu, and J. Roy. 2016. "Strategy Deployment in Healthcare Services: A Case Study Approach." *Technological Forecasting and Social Change* 113 (December): 429–437. doi:10.1016/j.techfore.2016.09.006.

Landry, S., and R. Philippe. 2004. "How Logistics Can Service Healthcare." *Supply Chain Forum: An International Journal* 5 (2): 24–30. doi:10.1080/16258312.2004.11517130.

Lasalvia, P., L. Prieto-Pinto, M. Moreno, J. Castrillón, G. Romano, N. Garzón-Orjuela, and D. Rosselli. 2019. "International Experiences in Multicriteria Decision Analysis (MCDA) for Evaluating Orphan Drugs: A Scoping Review." *Expert Review of pharmacoeconomics & Outcomes Research* 19 (4): 409–420. doi:10.1080/14737167.2019.1633918.

Lehnbom, E. C., K. V. Oliver, M. T. Baysari, and J. I. Westbrook. 2013. "Evidence Briefings on Interventions to Improve Medication Safety: Automated Dispensing Systems." *Australian Commission on Safety and Quality in Health Care* 1: 2.

Lynette, J. K., D. Barlow, A. Bithell, S. Hiom, S. Lord, M. Pollard, D. Roberts, C. Way, and C. Whittlesea. 2013. "The Impact of Automation on Workload and Dispensing Errors in a Hospital Pharmacy: Impact of Automation on Workload and Errors." *International Journal of Pharmacy Practice* 21 (2): 92–104. doi:10.1111/j.2042-7174.2012.00238.x.

Martelli, N., A.-S. Lelong, P. Prognon, and J. Pineau. 2013. "Hospital-Based Health Technology Assessment for Innovative Medical Devices in University Hospitals and the Role of Hospital Pharmacists: Learning from International Experience." *International Journal of Technology Assessment in Health Care* 29 (2): 185–191. doi:10.1017/S0266462313000019.

Martelli, N., M. Billaux, I. Borget, J. Pineau, P. Prognon, and H. van den Brink. 2015. "Introduction of Innovative Medical Device at French University Hospitals: An Overview of Hospital-Based Health Technology Assessment Initiatives." *International Journal of Technology Assessment in Health Care* 31 (1–2): 12–18. doi:10.1017/S0266462315000057.

Martinet, A., and H. Savall. 1978. "Martinet, A. et H. Savall (1978). Dysfonctionnements, Coûts et Performances Cachés Dans l'entreprise. Revue d'économie Industrielle [in French]." *Revue d'économie Industrielle* 5 (3): 82–94. doi:10.3406/rei.1978.995.

McKone-Sweet, K. E., P. Hamilton, and S. B. Willis. 2005. "The Ailing Healthcare Supply Chain: A Prescription for Change." *The Journal of Supply Chain Management* 41 (1): 4–17. doi:10.1111/j.1745-493X.2005.tb00180.x.

Miller, F. A., P. Lehoux, S. Peacock, V. E. Rac, J. Neukomm, C. Barg, J. P. Bytautas, and M. Krahn. 2019. "How Procurement Judges the Value of Medical Technologies: A Review of Healthcare Tenders." *International Journal of Technology Assessment in Health Care* 35 (1): 50–55. doi:10.1017/S0266462318003756.

Mitchell, M. D., K. Williams, P. J. Brennan, and C. A. Umscheid. 2010. "Integrating Local Data into Hospital-Based Healthcare Technology Assessment: Two Case Studies." *International Journal of Technology Assessment in Health Care* 26 (3): 294–300. doi:10.1017/S0266462310000334.

Nabelsi, V., and S. Gagnon. 2017. "Information Technology Strategy for a Patient-Oriented, Lean, and Agile Integration of Hospital Pharmacy and Medical Equipment Supply Chains." *International Journal of Production Research* 55 (14): 3929–3945. doi:10.1080/00207543.2016.1218082.

Noparatayaporn, P., R. Sakulbumrungsil, T. Thaweethamcharoen, and W. Sangseenil. 2017. "Comparison on Human Resource Requirement between Manual and Automated Dispensing Systems." *Value in Health Regional Issues* 12 (May): 107–111. doi:10.1016/j.vhri.2017.03.007.

Orlikowski, W. J. 2000. "Using Technology and Constituting Structures: A Practice Lens for Studying Technology in Organizations." *Organization Science* 11 (4): 404–428. doi:10.1287/orsc.11.4.404.14600.

Poulin, P., C. M. Lea Austen, C. D. Scott, E. D. Waddell, M. Poulin, and L. René. 2013. "Multi-Criteria Development and Incorportation into Decision Tools for Health Technology Adoption." *Journal of Health Organization and Management* 27 (2): 13. doi:10.1108/14777261311321806.

Radaelli, G., E. Lettieri, C. Masella, L. Merlino, A. Strada, and M. Tringali. 2014. "Implementation of EUNETHTA CORE MODEL® in Lombardia: The VTS Framework." *International Journal of Technology Assessment in Health Care* 30 (1): 105–112. doi:10.1017/S0266462313000639.

Rakovska, M. A., and S. V. Stratieva. 2018. "A Taxonomy of Healthcare Supply Chain Management Practices." *Supply Chain Forum: An International Journal* 19 (1): 4–24. doi:10.1080/16258312.2017.1395276.

Risør, B. W., M. Lisby, and S. Jan. 2017. "Cost-Effectiveness Analysis of an Automated Medication System Implemented in a Danish Hospital Setting." *Value in Health* 20 (7): 886–893. doi:10.1016/j.jval.2017.03.001.

Roussel, C., C. Carbonneil, A. Audry, S. Burtey, S. Faré, F. Langevin, S. Laroche, et al. 2016. "Impact Organisationnel: Définition et Méthodes d'évaluation Pour Les Dispositifs Médicaux." *Therapie* 71 (1): 69–82. doi:10.1016/j.therap.2015.12.003.

Sa'aid, H. B., and D. E. Stewart. 2011."Decision Making Processes for Introducing New Health Technology at Institutional Level: Decision Makers' Perspective". 11.

Sampietro-Colom, L., I. Morilla-Bachs, S. Gutierrez-Moreno, and P. Gallo. 2012. "Development and Test of a Support Tool for Hospital Health Technology Assessment." *International Journal of Technology Assessment in Health Care* 28 (4): 460–465. doi:10.1017/S0266462312000487.

Tarricone, R., A. Torbica, and M. Drummond. 2017a. "Challenges in the Assessment of Medical Devices: The MedtecHTA Project: Challenges in the Assessment of Medical Devices." *Health Economics* 26 (February): 5–12. doi:10.1002/hec.3469.

Tarricone, R., A. Torbica, and M. Drummond; for the MedtecHTA Project Group. 2017b. "Key Recommendations from the MedtecHTA Project: Improving the Conduct and Use of HTA for Medical Devices." *Health Economics* 26 (February): 145–152. doi:10.1002/hec.3468.

Tarricone, R., G. Callea, M. Ogorevc, and V. P. Rupel. 2017. "Improving the Methods for the Economic Evaluation of Medical Devices." *Health Economics* 26 (February): 70–92. doi:10.1002/hec.3471.

Temple, J., and B. Ludwig. 2010. "Implementation and Evaluation of Carousel Dispensing Technology in

a University Medical Center Pharmacy." *American Journal of Health-System Pharmacy* 67 (10): 821–829. doi:10.2146/ajhp090307.

Toba, S., M. Tomasini, and Y. Helio Yang. 2008. "Supply Chain Management in Hospital: A Case Study."*California Journal of Operations Management* 6 (1): 7.

Tsao, N. W., L. Clifford, M. Babich, K. Shah, and N. J. Bansback. 2014. "Decentralized Automated Dispensing Devices: Systematic Review of Clinical and Economic Impacts in Hospitals." *The Canadian Journal of Hospital Pharmacy* 67 (2): 138–148. doi:10.4212/cjhp.v67i2.1343.