

Syringeless power injector versus dual-syringe power injector: economic evaluation of user performance, the impact on contrast enhanced computed tomography (CECT) workflow exams, and hospital costs

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Objective: The utilization of diagnostic imaging has substantially increased over the past decade in Europe and North America and continues to grow worldwide. The purpose of this study was to develop an economic evaluation of a syringeless power injector (PI) versus a dual-syringe PI for contrast enhanced computed tomography (CECT) in a hospital setting.

Materials and methods: Patients (n=2379) were enrolled at the Legnano Hospital between November 2012 and January 2013. They had been referred to the hospital for a CECT analysis and were randomized into two groups. The first group was examined with a 256-MDCT (MultiDetector Computed Tomography) scanner using a syringeless power injector, while the other group was examined with a 64-MDCT scanner using a dual-syringe. Data on the operators' time required in the patient analysis steps as well as on the quantity of consumable materials used were collected. The radiologic technologists' satisfaction with the use of the PIs was rated on a 10-point scale. A budget impact analysis and sensitivity analysis were performed under the base-case scenario.

Results: A total of 1,040 patients were examined using the syringeless system, and 1,339 with the dual-syringe system; the CECT examination quality was comparable for both PI systems. Equipment preparation time and releasing time per examination for syringeless PIs versus dual-syringe PIs were 100±30 versus 180±30 seconds and 90±30 and 140±20 seconds, respectively. On average, 10±3 mL of contrast media (CM) wastage per examination was observed with the dual-syringe PI and 0±1 mL with the syringeless PI. Technologists had higher satisfaction with the syringeless PI than with the dual-syringe system (8.8 versus 8.0). The syringeless PI allows a saving of about €6.18 per patient, both due to the lower cost of the devices and to the better performance of the syringeless system. The univariate sensitivity analysis carried out on the base-case results within the standard deviation range confirmed the saving generated by using the syringeless device, with saving values between €5.40 and €6.20 per patient.

Conclusion: The syringeless PI was found to be more user-friendly and efficient, minimizing contrast wastage and providing similar contrast enhancement quality compared to the dual-syringe injector, with comparable CECT examination quality.

Keywords: dual-syringe power injector, syringeless power injector, economic evaluation, cost analysis, computed tomography, CT

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Introduction

There is a growing need for healthcare and the constraints on health expenditure is forcing our National Healthcare System (NHS; Sistema Sanitario Nazionale [SSN]) to

organize and rationalize economic-management issues with increased care. From the point of view of economic analysis, using a resource means losing the opportunity to utilize it in alternative ways, and this applies to fields other than healthcare as well. The value of a resource, from an economic point of view, is given by its opportunity cost; ie, the value of its use for the best of possible alternatives.¹ Economy evaluation in the healthcare sector aims at improving the employment of available resources by comparing costs (input) and consequences (outcomes) of a certain decision in the healthcare setting.² The purpose is to determine the economic value of different healthcare programs in terms of consumed resources and generated results. Economic evaluations in healthcare are therefore a supporting tool for decisions made by policy makers and professionals in the field, supplying additional information that increases the rationality of decision making. In the background of these considerations, the increased number of patients undergoing computed tomography (CT) requires a review of the tools used to carry out the analysis on patients referred to the hospital, optimizing management costs, and increasing efficiency.^{3,4} In clinical practice, contrast enhanced CT (CECT) makes up, on average, 40% to 60% of the volume of exams carried out in an average-sized hospital;^{5,6} therefore, the optimal management of all steps associated with the use of the necessary tools for CECT can positively and significantly influence the efficiency of operations, monitoring the various cost components in detail.⁷ The syringeless power injector (CT Exprès™; Bracco Injengineering S.A., Lausanne, Switzerland) is an innovative syringeless releasing device for contrast media (CM), allowing simultaneous loading of two bottles to carry out multiple CECTs without reloading the CM during the course of the exam; this translates into greater efficiency and less wastage of the medium.⁶ The purpose of the present study is to highlight, through an economic evaluation, how the use of syringeless power injectors (PIs) versus dual-syringe PIs for CECT is not only user-friendly and safe for use by the medical staff, but also allows to reduce equipment preparation time and CM releasing time, with decreased costs for the hospital. The results of this study will then be discussed with respect to their economic-management implications, trying to consider them within the framework of cost containment and rationalization currently under way in our NHS.

Methods

Study design

The purpose of this analysis was to evaluate the economic consequences of switching from dual-syringe to syringeless

PIs in CECT studies done on a primary outpatient and inpatient setting, considering the impact on examination and nursing time as well as on patient waiting time. An economic evaluation was performed with the aim of assessing the time required to carry out the exam with a dual-syringe and syringeless PI. The comparison was carried out in two separate settings, with different patient pathways, in order to describe different phases, times, and costs for each power injector. This allowed us to estimate a potential consumption or cost savings for the NHS in its temporal dynamics.

Patients and data collection

Consecutive patients referred to the Legnano Hospital between November 2012 and January 2013 for a CECT analysis were randomized into two groups. The first group was examined with a 256-MDCT (MultiDetector Computed Tomography) syringeless scanner CT Exprès™ (Bracco Injengineering), the other with a 64-MDCT dual-syringe scanner (Medrad® Stellant® D; Bayer HealthCare Pharmaceuticals, Berlin, Germany). Each patient was randomized and assigned to a different CT scanner room on the basis of room availability. Data on the time used by the radiologic technologists (RTs) in the patient analysis steps and on the quantity of consumable materials used were collected.⁸ The syringeless device allows the upload of two bottles of contrast medium, up to 500 mL; a bag of saline can be uploaded separately, and a disposable sterile connecting system of the various flows is available for each patient. The dual syringe device can load two syringes containing up to 200 mL of contrast medium and saline.⁶ At the end of the day, a RT recorded any wastage of contrast medium incurred for each system. The RTs were assigned the task to collect data on the performance of the two scanners, by means of predefined parameters such as: average contrast medium consumption, average time of contrast medium uploading, average time of preparation and leaving the examination room by the patient, contrast medium wastage, cost of disposing special wastes, preliminary assessment of the quality of the obtained images, and user-friendliness of the device.

Resource consumption and qualitative analysis

Costs were given a value according to Table 1, including the discount percentages obtained by the hospital and based on structural costs for personnel and consumable materials. The collected data allowed us to conduct a budget impact analysis⁹ in order to verify the potential saving of resources following the exclusive adoption of syringeless PIs to carry out CECT examinations. As for the quality evaluation of

Table 1 Resource consumption and costs

	Syringeless PI	Dual-syringe
	Unit cost	Unit cost
Device (VAT excluded)	€26,500.00	€26,462.00
Cost of consumable material per patient		
Bottle spike type A (30 mm)	€7.50	
used for five patients		
Day set III HP	€60.00	
Multipatient set	€30.00	
Patient line	€3.00	
Dual-syringe kit cost		€25.00
Other additional dual-syringe cost		€0.00
Cost per hour of technologist (RT)	€27.50	€27.50
Cost of the CM per milliliter used	€0.17	€0.17
Disposal cost	€0.57	€0.57

Abbreviations: CM, contrast media; HP, high performance; PI, power injectors; RT, radiologic technologist; VAT, value added tax.

the radiographic results by the RTs, the quality of contrast enhancement on CECT images was subjectively rated using a 5-point scale (5= excellent, 4= good, 3= fair, 2= bad, 1= no enhancement). The enhancing quality of the CT scans was reviewed by two radiologists with more than 10 years working experience. Qualitative evaluation of the PIs included a survey of the technologists' satisfaction using a 10-point scale (1–3= unacceptable to unreasonable, 4–6= reasonable to fair, 7–10= good to excellent) to include their satisfaction with the PIs for patient preparation, setup process, facilitating CM injection, and any safety concerns with the PIs.⁶

Statistical analysis

Data were entered into an Excel Spreadsheet 2013 (Microsoft Corporation, Redmond, WA, USA) by a single investigator. Patient gender, body parts studied, and CM volumes used in each group were assessed for study type bias. The qualitative variables were shown with the help of descriptive statistical methods such as means, frequencies, and percentages. The quantitative variables were described in terms of means and standard deviation.⁸ The statistical significance of any differences in the frequency distributions was tested using two-sample *t*-test. A value of $P < 0.001$ was considered statistically significant. In order to assess the robustness of the obtained results, a univariate sensitivity analysis was carried out with variation of the main parameters in a range corresponding to the standard deviation.^{2,8}

Results

The results on enrolled patients are shown in Table 2. During the 10 enrollment weeks, 2,379 patient underwent CECT examinations: 1,040 were examined with the syringeless method, the other 1,339 with the dual-syringe device. The

Table 2 Patient characteristics and distribution for syringeless PI versus dual-syringe device

	Syringeless PI		Dual-syringe	
	Mean	±SD	Mean	±SD
Patients	1040		1339	
Male	55%		53%	
Contrast media volume (mL)	85	15	85	15
Abdominal/pelvic	387		470	
Chest	273		370	
Head/neck	155		245	
Angiography	149		254	
Heart	76		0	

Abbreviations: PI, power injector; SD, standard deviation.

average consumption of CM was 85 ± 15 mL for both devices. The CM uploading time was 100 ± 30 seconds for the syringeless device versus 180 ± 30 seconds for the dual-syringe device, respectively. The average time for preparation and leaving the room by patients was 90 ± 30 seconds for the syringeless device and 140 ± 20 seconds for the dual-syringe system. Contrast medium wastage was 0 mL for the syringeless versus 10 mL for the dual-syringe device. Special wastes produced per patient were 0.03 kg for the syringeless versus 0.27 kg for the dual-syringe device; this parameter does not include the weight of CM bottles used.

The quality of radiographic results perceived by the RTs for the two operation systems was almost identical. Because of the user-friendliness of the device, technologists reported a higher perception of safety for the syringeless power injector

Table 3 Comparison of performance and radiologic technologist ratings between syringeless PI and dual-syringe power injectors

Patients	Syringeless PI		Dual-syringe		P-value
	1040		1339		
	Mean	±SD	Mean	±SD	
Performance					
Injection preparation time (seconds)	100	30	180	30	<0.000
Releasing time (seconds)	90	30	140	20	<0.000
Contrast media wastage per examination (mL)	0	1	10	3	<0.000
Contrast media (mL)	85	15	85	15	
Consumable material waste kg per person	0.032		0.27		
Technologist ratings					
PI performance	8		8		
User friendly	9		7		
Ease of patient preparation	10		4.8		
Ease of PI setup	8		9		
Safety concerns	9		8		
Treated patients (day)	22		20		

Abbreviations: PI, power injector; SD, standard deviation.

system (Table 3). The RTs' answers regarding the easiness of patient preparation, based on the evaluation system applied, showed a better result for the syringeless PI with an average score of 8.8 versus 8.0 for the dual-syringe device, with no statistically significant differences due to the sample size (Table 3). The model results (Table 4) show that the use of the syringeless device allows for time savings, with a consequential decrease in expenditure for patient management.

The analysis shows that the syringeless PI provides a saving of about €6.18 per patient, both due to the lower cost of the devices and to the better performance of the syringeless system. The total saving that could have been obtained in the hospital during the 70 days of use of the CT exprès™ syringeless device would have been around €8,700.00. The budget Impact analysis⁹ developed in Table 5 and Figure 1 shows the potential impact of the syringeless PI on hospital costs, with a conservative assumption of 20 daily scans for 250 days of hospital work a year. It is clear from Table 5 and Figure 1 that the biggest contributors to cost saving are the CM wastage with a syringeless power injector, which allows the user to completely use the bottle content, and the decrease in injection preparation time (–44%), with an estimated potential yearly benefit of €31,543.37 for the hospital. The univariate sensitivity analysis carried out on the base-case results within the standard deviation range confirmed the saving generated by the use of the syringeless device, with a saving ranging between €5.40 and €6.20 per patient.

Discussion

Our study identified the advantages of using syringeless PI versus dual-syringe devices during CECT scans, in order to make healthcare operators aware of the potential economic

and organizational advantages of syringeless PI devices. From a strictly operational point of view, this provides a decrease in costs for the hospital due to time savings with respect to preparation and CM release, along with the optimization of the use of CM. In this case, the innovation in the method of preparation and administration of the product favors a better organization of the workflow in the hospital, at the same time offering a better quality of the service provided and a higher level of safety as perceived by the RTs. Resorting to diagnostic imaging modalities has greatly increased over the past decade in Europe and North America, and continues to grow worldwide.¹⁰ In our study, the syringeless PI was found to be more user-friendly and efficient, allowing minimum CM wastage and providing similar contrast enhancement quality in comparison with the dual-syringe injector. The potential of scanning additional patients thanks to improved efficiency and cost savings from minimizing CM wastage make the syringeless PI more attractive to an outpatient and inpatient CECT practice.¹¹ The results of this study need to be interpreted while taking some limitations into account. The first limitation could be the adoption of a 2.5-month time interval for the syringeless PI versus dual-syringe device comparison, which may not be sufficient to highlight long-term effects. A second limitation is the patient sample size, which is not significant with respect to the examined Italian patients. The patient number was not large enough to establish the long-term performance of the syringeless device, its robustness in a busy CECT practice, and any risk associated with its continued use. However, compared to similar research work,⁶ we enrolled a higher number of patients (2,379 compared to 275), which allows us to consolidate and confirm the

Table 4 Cost analysis of the syringeless PI versus the dual-syringe device per patient

	Syringeless PI	Dual-syringe	Difference	%
Patients	1040	1339		
Device	€2.41	€2.23	€0.18	8%
Cost of disposable material per patient				
Bottle spike type A (30 mm) used for five patients	€1.20		–	–
Day set III HP (day)	€2.40		–	–
Multipatient set (day)	€1.20		–	–
Patient line	€2.40		–	–
Syringe cost		€10.75	–	–
Other additional dual syringe cost		€0.00	–	–
	€9.61	€12.98	–€3.55	–27%
Injection preparation time (seconds)	€0.76	€1.38	–€0.61	–44%
Releasing time (seconds)	€0.69	€1.07	–€0.38	–36%
Contrast media wastage per examination (mL)	€0.00	€1.68	–€1.68	–100%
Cost of the CM	€14.28	€14.28	–	0%
Disposal cost	€0.02	€0.15	–€0.14	–88%
Total per patient	€25.36	€31.54	–€6.18	–20%

Abbreviations: CM, contrast media; HP, high performance; PI, power injector.

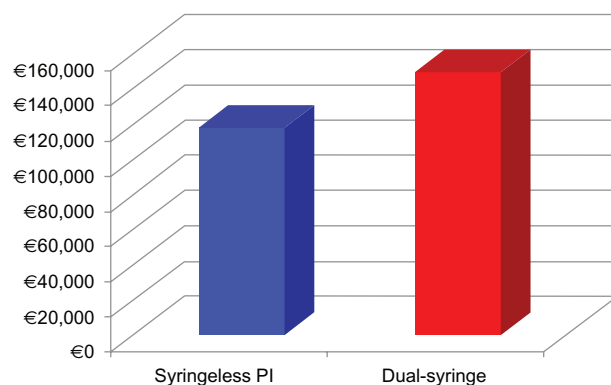
Table 5 Budget impact analysis: total cost of syringeless PI versus dual-syringe device for a 1-year simulation (20 patients/day per 250 working days)

	Syringeless PI	Dual-syringe	Difference	%
Machinery	€3,372.73	€3,122.52	€250.21	8%
Cost of disposable material per patient				
Bottle spike type A (30 mm) used for five patients	€6,000.00		—	—
Day set III HP (day)	€12,000.00		—	—
Multipatient Set (day)	€6,000.00		—	—
Patient line	€12,000.00		—	—
Syringe cost		€53,750.00	—	—
Other additional dual syringe cost		€0.00	—	—
	€39,372.73	€56,872.52	—€17,499.79	—31%
Injection preparation time (seconds)	€3,819.44	€6,875.00	—€3,055.56	—44%
Releasing time (seconds)	€3,437.50	€5,347.22	—€1,909.72	—36%
Contrast media wastage per examination (mL)	€0.00	€8,400.00	—€8,400.00	—100%
Cost of the CM	€71,400.00	€71,400.00	€0.00	0%
Disposal cost	€91.20	€769.50	—€678.30	—88%
Total cost	€118,120.87	€149,664.24	—€31,543.37	—21%

Abbreviations: CM, contrast media; HP, high performance; PI, power injector.

favorable results of the syringeless PI with a larger sample.⁶ Another important limitation is the fact that the study was carried out in a single hospital; the results of our study may be, for instance, applied to other hospital settings in the regional/national area, to define and compare mean standard operation costs for CECT. Finally, in this analysis, we didn't include any considerations regarding patient quality of life during diagnostic imaging examination.

The appropriate utilization of CM is of critical importance to reach diagnostic goals and to optimize the use of resources in modern health systems. Increasing the number of CT scans carried out on a scanner is therefore highly desirable to meet the growing expectations in CT demand and sustain departmental revenue gains. With the gradual decrease in CECT reimbursement for imaging centers and outpatient services, improvements in CECT productivity and reduced cost for operations are therefore very welcome.¹²

**Figure 1** Budget impact analysis: comparison of total cost of syringeless PI versus dual-syringe device for a 1-year simulation.

Abbreviation: PI, power injector.

Syringeless PIs represent a further advance in injector technology, allowing higher CM (1.000 mL load) and saline loading capacity during initial setup and therefore allowing up to 8 to 15 CECT examinations depending on the body part being scanned and the examination type. In addition, the overall process of facilitating a CECT examination is easier and quicker and is preferred by the RTs in our practice.⁶ The use of syringeless PIs allows for the gain of 130 seconds/patient on average versus dual-syringe PIs: this implies an average gain of 3,900 seconds (65 minutes) for every 30 scans that are carried out. Considering that the average time/exam in our hospital is calculated at 20 minutes, there is the possibility of increasing the number of scans by three for every 30 exams carried out. The budget impact analysis further confirms this result, highlighting a total saving of —€31,543.37 for the hospital, assuming the exclusive use of syringeless PIs, in 1-year in the hospital. As a comment on these results, it is useful to ask the following question: “What is the usefulness of knowing and containing the working cost of single operations, when the personnel cost is prevalently a fixed cost for the hospital; ie, is it unrelated to the various activities carried out?” We assume it is possible to apply the new technologies we have just described in some hospitals, through adequate organizational actions. The expected result will be to reduce the use of personnel and release a certain amount of work time. It is only natural to wonder whether these savings are real or potential.¹³ The answer, however, is the following: “It all depends on how the released work time will be used”. Only if the hospital is able to make good use of it, will we be able to state that the potential saving has turned into a real saving.¹³ The introduction of a technological innovation in

an ongoing work activity must be followed by the adoption of internal organizational processes so that the hospital can fully exploit the opportunities offered by the technological evolution. It is possible to think of some cases of “good alternative use” of resources made available through the use of syringeless PIs; for example, the saved time can be used to increase the offer of CECT scans (reducing waiting lists), or to supply new perceived quality indicators to further improve emergency room management or the management of departments dedicated to CECT exams, or to implement continuing education programs enriching the human capital available in the department. It has to be emphasized that human resources, if well managed and exploited, are the most precious asset of a hospital, since they can characterize the whole service offerings of the structure they work for.

Disclosure

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