Recovering value from used medical instruments: a case study of laryngoscopes in England and Italy

Viani C[a], Vaccari M[b], Tudor T[a1]

[a] School of Science and Technology, University of Northampton. Northampton, UK
[b] Department of Civil, Environmental, Architectural Engineering and Mathematics, University of Brescia, Brescia, Italy

Abstract

The healthcare sector has a relevant environmental footprint because of the significant materials throughput, the hazardousness of certain wastes it generates and the energy intensive treatment necessary to manage them. Using semi-structured interviews carried out with stakeholders from hospitals in England and Italy, this study sought to understand how best to recover value from used laryngoscopes. The findings suggest that despite differences in the use of single use instruments and the presence of a dedicated waste management department, sites in both countries face similar challenges, including limited communication between procurement and waste management staff, staff engagement, and end markets. The implications of these challenges and strategies for overcoming them are discussed.

Key words:

Circular economy, Healthcare waste, Medical waste, Laryngoscopes, Medical devices

[1] Corresponding author: Terry Tudor, terry.tudor@northampton.ac.uk. Tel.: +44 01604893372

1. Introduction

Within recent years, the concepts of the circular economy, including recovery of the intrinsic value of materials, have gained progressively more attention (Moscato, 2009; Pinjing *et al.,* 2013; UNEP and ISWA, 2015). Effective waste segregation and treatment can enable the reintroduction of materials in the economic chain, as reusable or recycled goods or in place of raw materials (UNEP, 2015). The EU Waste Framework Directive represents a step towards a circular economy through the incorporation of a waste hierarchy in the decision-making process, aiming at the promotion of value recovery from waste, through minimisation, reuse and recycle and the reduction of disposal (EC, 2008; 2014). Similarly, also national governments are trying to incorporate the concept into their national policies, by promoting green purchases and sustainable waste management practices. For example, the United Kingdom (UK) has sought to foster the transition to a 'green economy' at national and local levels (DEFRA, 2011). The Italian Government has also published the official guidelines for the national green public procurement policy (Italian Ministry of the Environment, 2008). While the Public Service Act in England requires commissioners to hold into consideration the environmental value, together with the economic and social ones, when buying goods for public services (Public Services Act, 2012). The decision-making process at the stages of purchase, use and disposal have inevitable repercussions for the type and amount of wastes produced, the risks to individuals and the environment, and the potential for value recovery (Haas *et al.,* 2015; Castellani *et al.*, 2015; Caniato *et al.,* 2015; Ghisellini *et al.,* 2015).

Although statistics concerning healthcare waste production and disposal at national level are available (e.g. on the websites of the Italian Ministry of Health and the English Health & Care Information Centre), there is limited information on how best to ensure value recovery in the management of used medical instruments. Therefore, using a case study approach, this study aimed to examine strategies for enhancing the recovery of value from laryngoscopes in Italy and England.

2. Managing healthcare waste and used laryngoscopes

Healthcare facilities produce a very wide range of waste streams, some of which are hazardous, but most are non-hazardous. Indeed, more than 80% of the waste generated in hospitals worldwide can on average be defined as 'general waste' (WHO, 2014). Good segregation is a key factor in limiting contamination, and containing risks (including the spread of infections), and reducing the quantity of waste treated as hazardous (Chaerul *et al*., 2008; Windfeld, 2015; De Feo and Malvano, 2009; Di Maria *et al.*, 2014; Eriksson *et al.,* 2005).

Greater sustainability within healthcare can be facilitated through green purchasing (Kaiser *et al*., 2001; Bergsma and Sevenster, 2013), having a dedicated waste manager (Tudor *et al.,* 2010) and effective segregation and management of the waste (Windfeld and Brooks, 2015; Lee *et al.*, 2004).

The legislative background on which the English and Italian health care waste laws have been developed is the European Waste Framework Directive (WFD) (EC, 2008). The WFD suggests the need to manage all types of wastes without endangering people and the environment and according to a hierarchy, aiming at recovering as much value as possible from it. In England, the Waste (England and Wales) Regulations mandates separate collection and that the segregated streams should undergo recovery operations (Defra, 2012). In addition, the Hazardous Waste Regulations outline stringent guidelines that must be followed when managing, transporting or treating hazardous waste (Defra, 2015). Lastly, the Medical Devices Regulations prescribes that consignment notes must be duly filled in including not only the components of a device but also the eventual presence of a battery (DH, 2013).

In the Italian legislation, the legislative decree DLgs. 152/2006, as amended by the DLgs. 205/2010, states that the first objective of a sound waste management (including healthcare waste), is precaution, namely the protection of the health of patients, operators and all people involved (Italian Government, 2010). It also explicitly includes the safeguard of the environment and the reduction of

wastefulness as essential recommendations that operators should follow. The D.P.R. 254/03 on clinical waste, called "special waste", is another key regulation in the field (President of the Italian Republic, 2003). The decree outlines seven different waste streams that fall under the definition of clinical waste, and how they should be stored and transported (Cottone and Cottone, 2008). In addition to this classification, it establishes that the recovery of value from certain streams, such as non-hazardous metals, should be incentivised (APAT, 2008).

A further fundamental aspect of hazardous healthcare waste management concerns the sterilisation of potentially infectious and contagious devices. The overarching piece of legislation is the European Directive 93/42 on Medical Devices, introduced in the Italian legal system through the Legislative Decree 46/97 (Scaini, 2010). The decree sets out the minimum acceptable requirements that sterilisation must satisfy, including the safeguard of patients' and other people's health, and the efficacy and reliability of sterilised instruments. Another important aspect that comes into play is the purchase of medical devices. This subject is covered by the "*Piano d'azione per la Sostenibilità Ambientale dei Consumi nel Settore della Pubblica Amministrazione*" (the action plan for the environmental sustainability of consumption practices within the public administration sector), a non-compulsory strategy issued by the Italian Ministry of the Environment together with the Ministry of Economy supporting green procurement in public administrations. The input to these guidelines comes from the European Union, which in 2001 issued the European Communication n. 274/2001, the most important document on green public procurement (Testa *et al.*, 2012).

2.1 Laryngoscopes

The present work focused on laryngoscopes, which are medical devices inserted into the mouth during a procedure to obtain a view of the patient's vocal folds or glottis (Fig. 1).

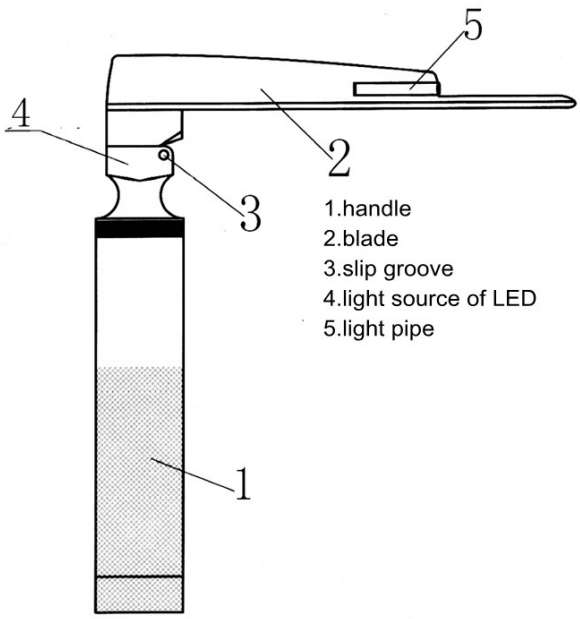


Fig. 1: A basic laryngoscope

Source: http://about-surgical-instruments.blogspot.co.uk/

Several reasons lay behind this choice. First, the high quality of the metal present in surgical instruments represents a valuable material to recover, as they are typically made from stainless steel (Ibbotson *et al.*, 2013). Second, the presence of a battery inside the laryngoscope. Batteries, if incinerated, could explode (DH, 2013) and contribute negatively to the noxious emissions of the treatment plant (Xarà *et al.*, 2015). This means that laryngoscopes, no matter if single use or reusable, should ideally be disassembled and the components effectively segregated (Dahlén and Lagerkvist, 2010).

Before being utilised – unless new – non-disposable laryngoscopes must be sterilised. Given the inevitable contact with mucosae, used laryngoscopes have to undergo either high temperature sterilisation or disinfection (Scaini, 2010). This process is very energy intensive and can create a significant environmental footprint, depending on the energy source of the hospital (McGain *et al.*, 2012). There is widespread support for the use of reusable over disposable from an economic point of view (Deprez *et al.*, 2000; Adler *et al.*, 2005; Morrison *et al.*, 2004; McGain *et al.*, 2012; Campion *et al.*, 2012). However, the economic efficiency depends on the number of times a device is used (Yang *et al.*, 2000).

During use, as the instrument gets into contact with sensitive and receptive body parts such as the mucosae of the mouth, they can potentially become infectious both for staff and patients (Williams *et al.,* 2010; Simmons *et al.,* 2000). Even when using disposable scope blades, reusable handles can still represent a possible source of contamination (Call *et al.,* 2009; Williams *et al.,* 2010). However, some medical products (e.g. single use versus reusable), are often preferred to others more based on anecdotal information and opinions, rather than on actual evidence (McGain *et al.,* 2012).

3. Methods

Several potential interviewees in both England and Italy, with key roles in the waste management or in the purchase department of a hospital, were initially contacted through known acquaintances of the research team. In the end, three sites for each of the two countries were selected, based primarily on access and the availability of data. Therefore, as it is often the case with interviews, the sample size was relatively small and was repeatedly adjusted (Denscombe, 2010). Face-to-face semi-structured interviews conducted in the respondents' offices were chosen, based in part on previous studies (Tudor *et al.,* 2010). The interviews in England were conducted during May 2015, while in Italy they were conducted from July to the beginning of September 2015. The questions were sent to the interviewees beforehand, along with a consent form and participant information sheet, as well as potential dates for the interview. Three interviews each were undertaken in Italy and England, giving a total of six interviews. Ethical approval for the study was granted by the School of Science and Technology at the University of Northampton.

The use of semi-structured interviews enabled an in-depth understanding of the site's policies and procedures, as well of the opinions and perceptions of the interviewee. The questions aimed to understand how used medical instruments, particularly laryngoscopes were disposed of and if there are potential options available for recovery, as well as potential future trends in the field of medical

devices, possible obstacles to value recovery and influencing factors in the decision making processes. Examples of questions asked included: How many inhalers and laryngoscopes does the hospital purchase every year? How much do these instruments cost? How many inhalers and laryngoscopes has the hospital discarded yearly in the past three years (2012 – 2013 – 2014) and what is the cost of their disposal? Which are the main obstacles to potentially recover more value, (e.g. Logistic, financial viability, public health issues, etc.)?

All interviews were audio recorded and later transcribed (Seidman, 2013). Analysis involved coding of the transcripts, a process composed of several steps: reading and interpreting the qualitative data obtained and analysing and marking all passages relevant to the aim of the research (Denscombe, 2010; Seidman, 2013). The data were categorised according to the phase they pertained to in the life cycle of the medical device analysed (i.e. procurement of the instrument, use and management (i.e. reuse or final disposal)).

The information from the interviews was contextualised with secondary data gathered using government and industry publications, that were publically available and had been published within the past five years.. More specifically, websites of healthcare sites of the Italian Ministry of Health and the English Health & Care Information Centre, provided quantitative data on the organisational structures, such as number of beds and wards, and the amounts and types of waste produced by the units. In addition, the Sanitary Medical Disposal Association (SMDSA), the Environment Agency and the Italian Institute for Environmental Protection and Research (ISPRA) supplied additional indications regarding the environmental cost of hazardous healthcare waste treatments.

4. Results

4.1 The English health care sector

Table 1 outlines the characteristics of three sites visited in England and the job roles of the interviewees.

Table 1: Overview of the health care sites visited in England and the job roles of the different respondents

SITE	N° of beds	N° of employee	N° of Interviewees		Job role
Hospital 1	1,100	13,000 < x < 14,000	2	Interviewee 1.1	Sustainability Manager
				Interviewee 1.2	Waste Manager
Hospital 2	1,300	8,000 < x < 9,000	1	Interviewee 2.1	Waste Manager
Hospital 3	1,000	8,000 < x < 9,000	2	Interviewee 3.1	Sustainability Manager
				Interviewee 3.2	Waste Manager

4.1.1 Phase one: procurement of the instruments

In each of the three sites visited, reusable laryngoscopes were progressively being replaced by single use stainless steel or mixed material devices (i.e. with a plastic body and metallic blades). Most interviewees agreed that single use for laryngoscopes, as well as for other medical instruments would increase. In Hospital 3, use of single use instruments was as a result of a combination of factors, mainly infection control and the market of purchased products, which was pushing for use of single use instruments.

> Interviewee 1.1: "we are seeing a real trend – in the NHS generally – towards disposable medical instruments, for one-time use instruments."

> Interviewee 2.1: "I think it might be part of a bigger trend to go towards single use as well. There's a lot more…not even devices, a lot more things that are becoming single use."

> Interviewee 3.2: “I wouldn’t say it’s a trend. I would say it is the market that brings them forward. And the regulation kind of supports it because it kind of fits in with the regulation.”

Together with the concern for infection prevention, another factor heavily influenced the type of devices purchased, namely the price. According to Interviewee 3.2, this element contributed “at least 40%” to the choice, but it usually did not include the whole life cost of the instrument. The only element considered during procurement was the amount each single piece costs, with neither maintenance nor disposal taken into account. According to Interviewee 3.1, not only are disposal costs neglected, but also all operational costs are excluded when evaluating the cost of a product:

> “we might end up buying something that is 50 quid (£s) cheaper, because we always buy the cheaper, because that cheaper is clearly without the cost of electricity, the cost of water, the cost of waste disposal. So it's linking the capital budget with the operational budget. That is probably one of the biggest challenges for organisations like us.”

In most cases, there was no interaction between the waste management team and the procurement department. Interviewee 2.1 noted that the waste management team did not come into play until the very last stage. Only then did the team find out if new instruments had been purchased, what they were and had to figure out how best to deal with them.

An additional concern that interviewee 2.1 raised on purchase regards the design of the single use laryngoscopes bought by the hospital. In order to properly dispose of an instrument with a fitted battery, it would be preferable to be able to disassemble the object and effectively dispose of the different components according to the legal provisions.

The general impression was that the market was contributing to the shift to disposable instrument, by promoting cheaper single use solutions instead of more 'expensive' traditional instruments. This impression was reinforced by interviewee 3.2 concerning the use of disposable instruments, who noted that the market "brings them [the single use instruments] forward". Furthermore, it was the market that influenced the potential recycling of the instrument, by designing "sealed units" that are not supposed to be disassembled or recovered.

Hospital 2 bought 150 packets containing 10 single use instruments each, between February 2014 and March 2015. This suggests that a hospital with 1,300 beds usually needs 1,500 laryngoscopes for 14 months, a rough average of 107 disposable scopes a month. During 2014/5, Hospital 3 ordered 17,700 packs, containing 10 disposable blades for laryngoscopes. Over the same period, 30 packs of 10 handles were purchased. The cost of disposable blades varied between £2.5 – 22.67.

4.1.2 Phase 2: Use of the instruments

The focus on single use as a way to avoid contamination was noted by Interviewee 1.1, who suggested that disposable instruments not only reduced pathways of infections but also "remove doubts" on potential contamination. Thus the perceived infection prevention played a key role in the use of the instruments. However, not all instruments used in the three sites were disposable. The use of reusable instruments was still widespread in Hospital 1, where the sterilisation unit was still actively used and has been expanded in order to respond to the needs of the site. Indeed, the presence of a sterilisation unit was inevitably a determining factor in the sites choosing which type of instrument to purchase.

Segregation of the instruments from other waste was done with the help of colour-coded packaging. However, the presence of so many different collection bins generated difficulties, mostly connected to the lack of space to locate the containers and the difficulty in training staff on how to properly segregate waste.

4.1.3 Phase 3: management of used instruments

Healthcare sites in the UK generated about 374,151 tons of waste during 2013 – 2014 (HSCIC, 2015). Table 2 illustrates that during 2013/4, nearly a quarter of the waste was recycled, with most of the rest landfilled, or sent for high temperature treatment.

Table 2: Treatment processes for waste produced by the health care sector during 2013/4

High temperature disposal waste weight (Tonnes)	Non burn treatment disposal waste weight (Tonnes)	Landfill disposal waste weight (Tonnes)	Waste electrical and electronic equipment weight (Tonnes)	Preparing for re-use volume (Tonnes)	Other recovery volume (Tonnes)	Waste recycling volume (Tonnes)
69,524	62,709	82,408	2,046	6,382	62,441	88,639
19%	17%	22%	1%	2%	17%	24%

Adapted from HSCIC (2015)

The cost of waste disposal for the year 2013-2014 was over £86 million, of which approximately £15.5 million was the cost of recovery, recycling and re-use (HSCIC, 2015). The difference of £70.5 million was spent for high temperature treatments, other treatments and landfill disposal. Although being only a rough calculation, from these amounts it is possible to say that the average cost of reuse, recovery and recycling was about £98.3/tonne, while landfilling, thermal and other treatments cost on average £326.5/tonne.

Single use instruments such as laryngoscopes were collected in bins and sent to high temperature treatment facilities. An attempt to recover value from these types of instruments was undertaken in Hospital 2, where metal devices were collected in specific boxes that were then picked up free of charge by the waste collector, although the hospital did not make any money. In exchange, the waste collector got well-segregated, high quality metal instruments that could be sold to companies recovering valuable materials. However, the continuous fluctuation in the prices of certain recyclables threatened to interrupt the service or to introduce

charges. The presence of plastic components in some models and a battery inserted in the sealed unit also presented a challenge to the hospital. In addition to design, logistics represent a significant obstacle to value recovery. For example, the site did not have enough staff to engage in a dismantling operation. A further challenge faced was the lack of space for storage. Waste contractors generally prefer to collect bigger bulks of materials, so the producer must be able to store its waste until the desired amount is gathered.

Hospital 2 was charged on average £513/tonne for incineration and £190/tonne to dispose of waste in hazardous landfills. The situation in Hospital 1 was slightly different. Reusable tools were still widespread, with disposable instruments a minority – even though they were increasing. Therefore, an attempt to limit the loss of value came from the reutilisation of sterilised instruments.

Hospital 3 had different options as it was equipped with an on-site Energy from Waste (EfW) facility. Thus the waste produced was not transferred to another site to be treated. However, the presence of an EfW on-site provided an incentive to the staff to dispose of more materials than necessary, the consequence being that recycling was difficult to implement. According to Interviewee 3.2:

> "We are our worst enemy in one way, because a lot of stuff goes through that probably because we can…legally it's fine, sustainably mmm…it's a bit of a bone of contention. The attitude is 'We have an on-site incinerator, we don't have to worry quite as much because we are not paying commercial prices for our waste'."

Thus a significant role was played by the waste management behaviours of staff. Further to this, according to Interviewee 3.2, lack of time and staff engagement were also important challenges to effective waste segregation:

> "We are getting less value back for scrap metal because our scrap metal contractor is having to get the plastic part off it. So we are going to lose some money out, we are not going to get as much, whereas if

we had somebody here to get that bit off, we could probably use a different contractor or they'd give us a higher value."

4.1.4 Practices of value recovery from used metallic devices in England

Figures 2 – 4 outline the overall management systems for the instruments, by the three hospitals.

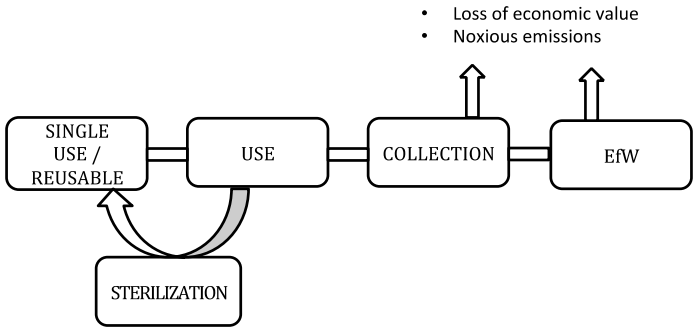
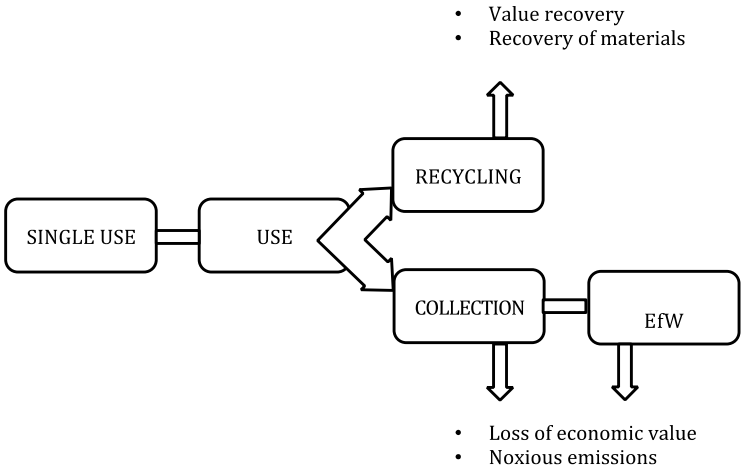


Figure 2: Life cycle of metallic medical instruments in Hospital 1



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371 **Figure 3: Life cycle of metallic medical instruments in Hospital 2**

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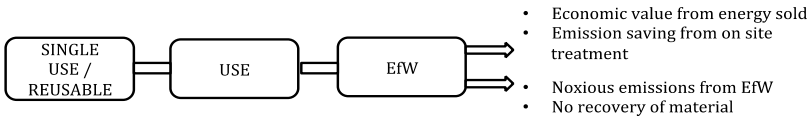

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Figure 4: Life cycle of metallic medical instruments in Hospital 3

4.2. The Italian health care sector

Table 3 lists the characteristics of the sites and the job roles of interviewees at the Italian hospitals.

Table 3: Overview of the health care sites visited in Italy and the job role of the different respondents

SITE	N° of beds	N° of employee	N° of Interviewees		Job role
Hospital 4	1,600	8,000 < x < 9,000	1	Interviewee 4.1	Sustainability Manager
Hospital 5	600	2,000 < x < 3,000	1	Interviewee 5.1	Chief Medical Officer
				Interviewee 5.2	Health Engineer
				Interviewee 5.3	Nursing Staff
Hospital 6	1,400	5,000 < x < 6,000	2	Interviewee 6.1	Purchase Dept. officer
				Interviewee 6.2	Eco Manager

4.2.1 Phase one: procurement of the instruments

In Italy, in order to purchase any kind of good or service, hospitals – like any other public structures – have to participate in tender notices. Tenders take place at Regional level and are managed by an external organisation (e.g. for the Tuscan region it is ESTAV (Ente per i Servizi Tecnico-Amministrativi di Area Vasta, i.e. Public Body for technical and administrative services of large areas), which runs them in response to the needs of all health care sites in the Region. Tender processes are particularly long and bureaucratic processes: according to Interviewee 6.1, they can easily last 2 years. The procedure is divided into several steps, which involves different departments and stakeholders of the health care sector. A key step concerns the cost evaluation of the new equipment that they are purchasing. For the three sites, at the time of purchase, neither the environmental impacts nor the final cost of disposal was taken into account. Ministerial guidelines for green public procurement were totally disregarded at the hospitals visited, in favour of other factors such as the efficiency of the instrument/device bought and its cost. This aspect was confirmed by Interviewee 5.3, who noted:

> "give guidelines to ESTAV, not only on waste management, waste disposal, but also on other passages, on reconditioning, […]. There are like separate containers in the company government. I do a thing and you do another one that will certainly increase the final cost of the process but since it is divided between you and me, I do not care! I saved money! Then if costs increase, it is an issue that concerns someone else, someone dealing with waste."

Thus the final cost of disposal was not taken into account at any stage during procurement. Lack of communication, appeared to be one of the reasons responsible for the situation. A significant exception to this lack of collaboration between departments was represented by Hospital 4, where the purchase of larger devices, furniture and machinery employed a different approach. This policy was the result of collaboration and of the combination of the interests represented by different departments. It meant that the site did not purchase or own any of these instruments but rather it solely rented them. A monthly rental charge was paid to the producer, who in exchange took care of maintenance, substitution and disposal of the product. Although being slightly more expensive as a whole, this mode of operation was preferable according to Interviewee 4.1 because it guaranteed a steady, known cash outflow and did not require a huge start-up capital investment. Smaller devices such as laryngoscopes, were excluded from this type of management (with the exception of highly specialised instruments, such as fiberscopes), although Interviewee 4.1 did not seem adverse to the idea of extending the approach to all instruments. A key reason behind the more circular approach adopted lay in the presence of a board meeting, held regularly at regional level between staff of hospitals, representative of the industry and of the regional government. During these meetings, guidelines for the purchase department and for the different wards were issued to encourage efficiency.

All three sites used reusable laryngoscopes. All sites were equipped with a sterilisation unit, and did not see any economic benefits in shifting to disposable tools. Broad support for reusable laryngoscopes was shown in Hospital 5, where

all interviewees agreed that the pros of reusable outweighed the disadvantages of disposable instruments.

> Interviewee 5.3: Disposable is not reliable
> Interviewee 5.1: Then it has a significant cost!
> Interviewee 5.3: It is a tool that can be sterilised very well, the blade at the end.

Interviewees in Hospital 5 stated that there was a tendency towards increased use of single use instruments, unless a different response to multi resistant organisms was found. In contrast with the other two sites, Hospital 6 was already starting to use disposable instruments, although they still represented only a small percentage. According to the interviewees, three main factors were responsible for this choice: First, single use instruments met the necessity for precaution - especially from the perspectives of legislative compliance and infection prevention. Second, it followed a growing trend across the sector. For example, Interviewee 6.1 argued that:

> "Unfortunately there isn't the same policy even in the same hospital! Someone wakes up, wants single-use, explains why and maybe even gets it. All the rest of the hospital keeps on using reusable. Random! [...] We didn't have it before, it was all reusable. They do it for medico legal reasons essentially, or for a fashion. Of course it costs more, but is also more comfortable."

Third, the limited capacity of the internal sterilisation unit in Hospital 6, where waste management was subcontracted to a private company.

According to Interviewee 5.1, in 2014, the hospital purchased 48 reusable laryngoscopes for a total of €2,928. The average cost per instrument was therefore about €61. This was clearly a higher price than that of a single use laryngoscope, but it was balanced out by the extensive use over the years.

4.2.2 Use of the instruments

At the three sites, no concrete preference towards the types of devices was expressed. Furthermore, no explicit guidelines had been issued, neither from infection control departments nor from the hospital management, therefore none of the sites was facing overt pressure to switch to disposable instruments. However, it was becoming evident that possible contamination could take place and so disposable instruments were starting to be purchased. At the same time, it was also recognised that adequate staff training played a fundamental role in any shift in practice.

The lifespan of reusable instruments was extended as much as possible, by transferring the instruments – when possible – from one ward to another. In Hospital 4, certain surgical instruments were transferred from the operation room to different departments, before eventually ending up in the veterinary department. According to Interviewee 4.1, a surgical instrument, when properly managed, could easily last more than 20 years.

4.2.3 Management of the used instruments

The amount of single use disposable instruments as a percentage of the total waste generated in Italian health care sites was very low. According to Interviewee 5.2 "*the incidence of these products on the total waste tends to zero*". However, there was limited value recovery from metal waste at the three sites.

A key difficulty arose from the lack of functioning markets, to which recovered materials could be sold. According to Interviewee 6.2, the crucial “mistake” was the creation of consortia for the management of raw materials (e.g. paper, plastic, glass, but also batteries and electronic devices). In Interviewee 6.2's opinion, consortia disincentivised small scale collection, which was no longer cost-effective, reducing the possibility to recover raw materials. Interviewee 5.2 also shared this opinion, stating that:

> "recovery can be done cost-effectively by huge providers, who have large quantities and also heavy bargaining power. [Company X] does have a remarkable turnover. For us that we could dispose of... What? Maybe 30, 40 kg of stainless steel a year, it is complicated. In fact logistics costs would counterweight..."

Company X was in charge of collecting and sterilising metal instruments and devices from over 50 hospitals.

In Hospital 4, laryngoscopes were collected and the batteries segregated from the metal part, which was collected by the waste contractor. The site was charged for the collection, however, according to Interviewee 4.1, they did not benefit from price fluctuations in the market. Thus even if the price of recycled materials rose, they would not benefit from a reduction of the charges. The cost of waste incineration for Hospital 4 was on average €1,270/tonne (about £923/tonne - while other types of disposal could cost up to €2,630/tonne (£1,913/tonne) in case of hazardous chemicals. However, the cost charged by the waste contractor was inversely proportional to the amounts produced. Thus the more the facility generated, the lower the charges per tonne. These prices were considerably higher than those provided by Hospital 2.

Table 4 suggests that quantities of hazardous healthcare waste produced in Italy between 2011 and 2012, were relatively constant. Depending on the definition used, the amounts vary considerably (ISPRA, 2014). Between the years 2011 and 2012, the national coding used to distinguish different economic activities - the so-called ATECO codes - changed. In addition to this, data diverge substantially if calculated according to the European Waste Catalogue (EWC), which is yet again different.

Table 4: Healthcare waste generation in Italy according to the ATECO code and the EWC, during 2011/12

Year	Waste according to ATECO coding		Waste according to EWC	
	Non Hazardous	Hazardous	Non Hazardous	Hazardous
2011	57,964	146,330		

2012	55,215	156,759	4,778	141,340

Source: ISPRA (2014)

The most widespread treatment for hazardous healthcare waste in Italy is incineration without energy recovery, while only a small fraction was treated in EfW facilities (Table 5).

Table 5: High temperature treatment for healthcare waste in Italy, during 2011/12

	Incineration		**Incineration with Energy Recovery**	
	Non Hazardous	Hazardous	Non Hazardous	Hazardous
2011	6,883	128,186	N.A.	N.A.
2012	6,414	108,194	451	13,198

Source: ISPRA (2014)

Laryngoscopes can be disposed of with hazardous or non-hazardous metallic waste, depending on whether the instrument has come into contact with a potentially contagious patient, if it has been sterilised or if it has not been used.

4.2.4 Practices of value recovery from used metallic devices in Italy

All three hospitals managed their instruments and metallic waste in the same way as represented in Figure 5.

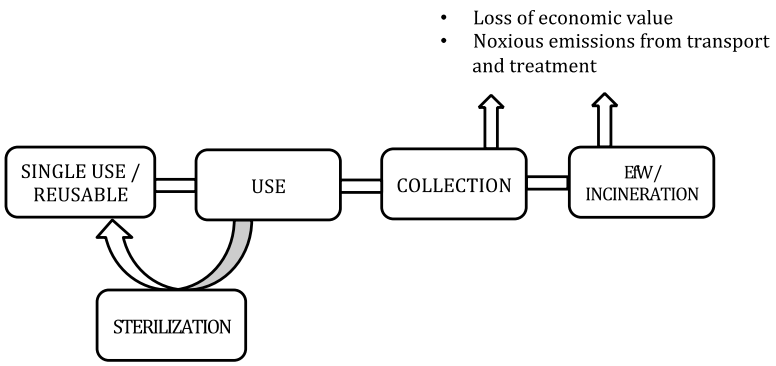

Figure 5: Life cycle of metallic medical instruments in Italian Hospitals

The loop displayed on the left side of the Figure (reusable instruments – use – sterilisation) can last for a relatively long time span, while the amount of devices that undertake the right path of the process (collection – EfW/incineration) is marginal.

5. Discussion

There were two key differences in the approaches taken between the sites in the two countries. First, there was a difference in the usage of single use instruments. The generation of waste from the use of medical instruments was relatively limited in Italy due to the widespread use of reusable devices. Single use instruments were considered more expensive by all the interviewees, and were used in limited quantities. Despite some single use instruments being in use, neither infection control nor the market had yet led to a substantial change in the traditional approach to utilising reusable medical equipment. Despite the positive circular

process displayed at the sites in Italy, little value recovery from the metal instruments was being intentionally carried out.

Unlike in Italy, the use of single use instruments was wide spread at the sites in England. The rationale for this approach lay in two main factors: First, infection control and prevention departments played a significant role in the decision making processes at the sites. Similarly to previous studies, use of these instruments was seen as a means of enabling greater infection control and prevention (Campion *et al.,* 2012; Ibbotson *et al.,* 2013; McGain *et al.,* 2012;Ibbotson *et al.,* 2013). Disposable stainless steel or plastic instruments reduce the number of people getting in contact with a potentially infected object, decrease the movement of the same object between the place of use and its final disposal and lastly, does not depend on the efficiency of a sterilisation process (McGain *et al.,* 2012). Second, another key factor driving the use of the instruments was costs. For most of the participants in England, the perception was that costs were lower for single use items. However, these costs often did not take into account waste disposal at the time of purchase (Ibbotson *et al*, 2013; Adler *et al.*, 2005; Morrison *et al.*, 2004).

Another key difference between the two countries was with regards to the presence of dedicated waste management departments. The structure of the departments in Italy rarely included the presence of a waste manager. However, in all of the sites in England, either a single person or a whole team (up to 37 people in the case of Hospital 1) was employed. Hospital 4 in Italy was an exception, however, this resulted solely from a particular synergy in the structures at the regional level. While the eco manager in Hospital 6 cannot be compared, as their responsibilities and tasks were not specifically those of a waste manager. A consequence of the difference in department sizes was therefore differences in the provision of resources and focus on management of wastes. Interesting, though, despite this difference, the sites in both countries were practicing value recovery

from the instruments. Despite the high usage of single use instruments, the English sites were practicing reutilisation. Hospital 2 was also specifically separating out its medical instruments (even though fluctuations in prices and limitations in space did make this challenging). At the same time, if value recovery is looked at in a wider sense (e.g. extending product life), the Italian sites, while it was not a focus, were also indirectly practicing recovery of value from the instruments.

The main reason for the difference between the two countries was due to the availability of monies. The sites in England, generally had greater access to finances and thus to resources.

Despite these key differences, there were similar issues in both countries, namely: limitations in communication and end markets, , the presence of a sterilisation unit and staff engagement, which ultimately impacted upon value recovery.

5.1 Communication

Limitation in communication between different departments was a fundamental issue in most cases. Almost all the sites noted that there was a lack of collaboration between the procurement and waste management teams (or equivalent), which had important consequences on whole life cost considerations. Communication is generally recognised as a fundamental aspect of sustainable purchase (Millett, 2000; Kaiser *et al.*, 2001). Given the lack of communication, managing the waste was not factored in when evaluating the price of instruments, even though the disposal costs and environmental risks were potentially high (Finnveden *et al.,* 2005; Ibbotson *et al.*, 2012; Tekin *et al.*, 2015). The exchange of information between staff in the two departments would be essential in order to include aspects such as the dismantling of an instrument, the cost of a waste treatment, etc. into the evaluation process at the time of purchase. Furthermore, this could indirectly influence the producers of metallic medical instruments, which could eventually lead to adaptation to the necessities and requests of health care sites.

The one exception to this general lack of communication between departments was Hospital 4, where regular board meetings were held between the waste manager and other key stakeholders. The result was a set of interesting initiatives, such as the use of leased equipment to avoid disposal costs, the introduction of guidelines that the procurement department had to follow, and an evaluation and reward system to engage staff with more sustainable practices.

5.2 End markets

In both countries, but particularly in Italy, limitations in end markets existed. Most of the interviewees in both countries were of the opinion that the market was progressively pushing to incentivise the use of single use instruments. However, the development of end markets is largely dependent on the manufacturers of medical devices to design instruments in a way to enable easy and quick disassembly (Maris *et al.*, 2014; Bergsma and Sevenster, 2013). With limitations in disassembly, segregation was consequently very difficult and this impacted upon the potential value that any hospital could recover from an instrument. According to Interviewee 3.2, if instruments composed of different materials were completely dismantled at source, they would guarantee a higher income to the hospital. However, an issue at all of the sites was limitation in storage space. Adequate on-site storage space is crucial to enable effective segregation of materials (and therefore a cleaner feedstock for waste contractors and reprocessors) (UNEP and ISWA, 2015). Storage is also a fundamental prerequisite in order to accumulate enough materials to make collection and transportation cost effective (Williams, 2007). Indeed, the level of segregation of the feedstock materials determines the quality and thus the price that can be commanded.

A further barrier was the inadequate structure of the recycled materials' trade. Although an end market for these products is present in both countries, many interviewees suggested that the absence of potential buyers of recycled materials

was one of the key obstacles to value recovery. The market appeared to be structured in a way to favour only big producers or suppliers of material, while if only small amount of metal are recovered, it was not cost effective to collect and sell it. Only in Hospital 2 was metal recovery taking place. However, Interviewee 2.1 appeared sceptical about the prospects of the collection, given the steady drop of metal prices.

5.3 The presence of an on-site sterilisation unit

Sites equipped with an adequately sized unit perceived the use of disposable instruments as more costly. For example, Hospital 3 paid about £57,000 to purchase single use blades, laryngoscopes and reusable handles over one year, while Hospital 5 spent €2,928 (approximately £2,131). This equates to an average of £57 per bed for Hospital 3, while Hospital 5 -(an Italian site) spent less than £4 per bed.

There is wide acceptance of single use instruments from an economic point of view (Deprez *et al*., 2000; Adler *et al*., 2005; Morrison *et al*., 2004; McGain *et al.*, 2012; Campion *et al.*, 2012). However given the lack of specific data, and the case specificity of the elements that must be taken into account, it cannot be concluded that sterilisation is more cost effective than the use of disposable instruments in the analysed cases. However, what can be stated is that the presence of a well-functioning and large sterilisation unit changes the approach towards the type of instruments to be purchased and is a fundamental prerequisite in order for reuse to be a cost effective option in lieu of disposable instruments (Ibbotson *et al.*, 2013). Indeed, the only Italian site where the presence of disposable instruments was increasing was the same one that had a smaller, privately managed unit.

Disposable instruments were initially meant only for exceptional contexts where effective decontamination of medical instruments could not be assured (Ibbotson *et al*., 2013). Economic and political considerations, together with the evolution of the market and of infection control practices, have since contributed to pushing

either for the implementation of sterilisation or for a shift to disposable instruments. For what concerns infection control, little evidence is found to support disposable instruments over reusable ones. First, various writers assert that even single use blades do not fully avoid spreading of contamination (Williams *et al.*, 2010; Call *et al.*, 2009; Millett, 2000; Simmons, 2000). While others have found that reusable handles do not pose a concrete risk of contagion to patients or staff (Quareshi *et al.*, 2008). Second, sterilisation alone cannot guarantee the complete decontamination of an instrument. Indeed, incorrect procedures, insufficient training and lack of personnel play a role, even if sterilisation units are functioning and well equipped (Scaini, 2010).

A further important feature that can influence value recovery is the presence of an on-site treatment facility. The EfW facility at Hospital 3 guarantees an economic return to the site for the infectious and sharps waste generated by the site. Even though it can be argued that energy is being recovered, the plant, however, "disincentivises" – in the words of Interviewee 3.2 – further material recovery and recycling.

5.4 Staff engagement

The last, though fundamental, aspect that influenced the recovery of value from metal surgical instruments in the two countries was staff engagement. Staff training and engagement are fundamental for good resource segregation (Windfeld and Brooks, 2015; Tsakona *et al.*, 2007; Hengevoss *et al.*, 2012). Beliefs can also deeply influence the purchasing decisions, in particular the uptake of green procurement practices (Testa *et al.*, 2012). The lack of a strategic focus and interest in incorporating the concepts of green procurement was a key factor in the purchase of the types of laryngoscopes. Personal interest or knowledge can also contribute to the efficiency of a department or to the introduction of new practices (Tudor *et al.*, 2008). Evidently, the opposite is also true, with a lack of interest in a certain topic, resulting in it being ignored. For example, only Hospital 4 among the three visited sites in Italy had a dedicated waste manager, who contributed to the

effective functioning of waste management practices at the site. Conversely, the observed level of commitment and expertise was relatively high at all visited sites in England. Implementing the concepts of the circular economy requires the direct involvement of people as active participant to the process, instead of being a passive representative of the throwaway culture as pointed out by Interviewee 6.1 (Ghisellini *et al*., 2015).

6. Conclusions

While there were differences in the approaches between the sites in the two countries, particularly related to the use of single use instruments and resource provision, practices and challenges were largely similar. For example, both countries faced difficulties in the development of end markets, as well as limitations in communication between related departments, and staff engagement.

While there were elements of value recovery, particularly in the case of the English sites, where there was a greater focus on sustainable waste management, there was significant room for improvement in both countries. This improvement, however, would require a more stream lined approach both at the site level (i.e. more joined up thinking between procurement and waste management departments and opportunities for effective waste segregation), as well as at the wider level (i.e. the development of sustainable end markets). However, the key factor in ensuring greater circularity in managing used laryngoscopes, is upstream, at the procurement of the devices. Indeed, even before, at their manufacturer to enable ease of disassembly. All of the respondents (except Interviewee 4.1) indicated that no consideration was paid to waste at the time of purchase either in England or in Italy.In addition, the choice concerning which type of device to buy was linked more to other considerations, such as efficiency, price and the facilities of the hospital, rather than to the whole life costs.

Rising quantities of single use medical instruments, including laryngoscopes, in England and increasingly in Italy suggests the need for more circularity in the manner in which they are managed. This more circular approach would not only

ensure cost savings, but also ensure legislative compliance. In order for this approach to become reality, key organisational factors (e.g. greater dialogue between relevant stakeholders, and staff engagement), as well as logistical factors (e.g. end market development), need to be addressed. If these challenges can be overcome, then there should be significant environmental and economic benefits realised, not only for the management of laryngoscopes, but also for other used medical devices as well.

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