Using the T-DOC® software application to calculate sterilization costs
S. Caquas1, C. Chapirot1, A. Coquard1, B. Dieu1

Summary:
Using T-DOC® traceability software to calculate sterilization costs

New strategies for subcontracting, the development of single-use material, and the implementation of new legislation have made knowledge of the costs of sterilization services essential. At the University Hospital of Rouen, the comprehensive traceability of the sterilization process and the associated instrument traceability are assured by means of the T-DOC® software application. Once vital parameters have been defined, the software's cost calculation functions enable the determination of specific product costs for each type of surgical goods. Costs are broken down into five categories: Usage, cleaning, sterilization, handling, and packing. The number of surgical instruments per box and the sterilizer volume are the main cost variation factors. For example, the cost of the total sterilization process for the abdomen and wall instrument trays of the uro-digestive surgical unit have been estimated as EUR 16,- and EUR 8,- excluding tax. The two-fold assessment of costs - per product and on the basis of process stages - is not only a steering tool for sterilization activities; in addition, it constitutes an opportunity for optimizing customer/supplier relationships.

Keywords: Sterilization, cost assessment, product, electronic traceability

Introduction

New strategies for subcontracting - to private entities (2) and to other health institutions (6) - associated with the development of single-use material have made knowledge of the costs of sterilization services essential. At the same time, the evolution of the health system and the associated deployment of the new governance (8) and incitement to contract services out between centers have reinforced the necessity for each establishment to be aware of the costs of the activity it generates. In the case of surgical centers, this process of contracting out is even more important, since the costs of sterilization have to be taken into account. In the light of these problems, the hospital management must constantly review the merits of continuing in-house sterilization activities and - in order to do this - must be able to assess the costs of these services (19, 20).

In the case of the University Hospital of Rouen, an initial analysis of sterilization operating costs gave rise to a decision to continue this activity following the imposition of the obligation to comply. In parallel, in February 2005 a system for ensuring the comprehensive traceability of the sterilization process and associated instrument traceability was put in place using the T-DOC® software application. This was implemented in order to respond to legislatory requirements regarding health safety (3) and also in order to provide a reliable tool for the management of everyday activity.

The main objective of this project is to assess the costs of sterilization and, in particular, to determine the specific production costs for each type of surgical goods or "product", whether this takes the form of an instrument tray or an individual instrument, using the cost calculation functions provided by the T-DOC® software application. These specific costs for each product will enable an accurate overview of costs incurred through sterilization and of the activity of a surgical unit during a given period. Furthermore, following an analysis of the source and structure of the production costs it will be possible to extrapolate a simplified cost calculation method.

Presentation of sterilization activities at the University Hospital of Rouen

The University Hospital of Rouen has 2,400 beds of which 25% are surgical beds. All medical specialities are brought together in 11 surgical units and 2 surgical departments shared out over 30 operating rooms. 24,000 operations were carried out in 2007. The sterilization centre is open 7 days a week, from 7 a.m. to 8.30 p.m. on weekdays and from 9 a.m. to 5 p.m. at the weekend. 6 nurses (nurse practitioners [IDE] and operating theatre nurse practitioners [IBODE]) and 36 operatives are responsible for production here. The total sterilization volume in 2008 was 4,785 m³, consisting of 193,740 units which were registered in T-DOC. The surgical goods are pre-disinfected by the surgical units and received into a washing area with 9 instrument washer-disinfectors with 16 baskets and a spray-washing chamber with a 40-basket capacity. The actual sterilization is carried out using 6 sterilizers (one sterilizer each with a capacity of 10, 6, and 4
baskets respectively and 3 sterilizers with 8 baskets each). A probe is placed into each processed batch. Instrument traceability takes effect at the reassembly/packing stage. At this stage, each instrument is scanned individually to ensure its traceability (figure 1).

Fig. 1: Instrument scanning

A connection with the patient record management system enables each instrument to be linked to a patient for a defined operation in order to allow closed-loop traceability of the movement of instruments between the surgical units and the sterilization centre.

Methodology

Study scope

The scope of work of the study was defined on the basis of the scope of work of the surgical unit in order - on the one hand - to cover a wide range of products with regard to their packaging and instrumentation and - on the other hand - to create a homogenous test basis for invoicing. Of the 11 surgical units, it was decided to use the uro-digestive unit for various reasons. One of the main reasons was the wide variety of instruments used due to the high number of individual instruments required in this area, the fact that this unit uses coeliosurgery instruments, and the fact that instrument trays of differing complexity are used. In addition, experiences gathered when determining the production costs for this type of goods might be useful for subcontracting to medium-sized entities owing to the high level of activity in the uro-digestive field of surgery.

Thus, it was decided to use steam-sterilized uro-digestive instrumentation for the pilot study on cost calculation methodology. The specific instrumentation comprised the following: 104 trays in double-sided non-woven wrap, 15 trays in containers, and 275 instruments in individual packaging.

Note that only the costs incurred by the sterilization centre are assessed in this study. The pre-disinfection process and transportation/storage of the surgical instruments are the responsibility of the surgical unit staff; the costs of these activities could form the subject of a complementary study as part of an approach that aims to evaluate the global costs of sterilization at hospital level.

It is also important to point out that the numerous aspects of parameterization and computer-based implementation in T-DOC are not handled in this article due to their great complexity. The data was entered into T-DOC between May and August 2009.

Calculation of sterilization costs using T-DOC traceability software

The T-DOC calculation method breaks down the costs for each product into five categories: Usage, sterilization, washing, packing, and handling. The six fields (one for each cost category and a "Total" field) are filled in automatically on the basis of parameterized data in the software for each cost category and product category (figure 2).
Usage costs

This category allows the amortization of the cost of surgical instrumentation to be taken into account. At the University Hospital of Rouen, these costs are attributed to the budgetary accounts of the surgical units, meaning that the calculation of usage costs is not applicable in some cases.

A possible usage of this category in T-DOC concerns single-use material. Effectively, it is possible to attribute the price of all sterilizable single-use material that forms part of an instrument tray to each sterilization cycle.

Sterilization costs

This figure is calculated by sharing the cost of the sterilization cycle amongst the products making up the batch. Thus, these costs are attributed to each product in accordance with the volume it takes up in the sterilizer. The calculation is based on the determination of 3 parameters:

- The cost of the sterilization cycle
- The basket capacity of the sterilizer
- The volume of each product expressed as a "sterilizer volume index" calculated as 1 divided by the number of baskets occupied by the product

The sterilization costs for a product are thus calculated by T-DOC using the following formula:

\[
\text{Cost of sterilization cycle in sterilizer / basket capacity of sterilizer} / \text{product sterilizer volume index}
\]

Washing costs

This figure is calculated in accordance with the same logic as that used for the sterilization costs.

Packaging costs

This figure is calculated on the basis of the type of packaging used for each product and the associated consumables.

Handling costs

This figure reflects the labor costs and is calculated on the basis of the following 2 parameters: The handling time (i.e. the amount of time taken by the sterilization personnel to process each piece of material) and the hourly labor rate for the personnel.
Data collection

Data relating to usage costs

This data relates to the invoicing of single-use consumables that form part of instrumentation trays. This charging structure has been restricted to aluminum cups. All other consumables have been disregarded due to their low cost in relation to the amount of work required to bill them separately.

Data relating to sterilization costs

Determination of the average cost of a sterilization cycle:

The costs of a sterilizer cycle are broken down as follows:

- Fluid costs: Electricity, water purified by reverse osmosis, and softened water used in 1 cycle
- Costs of consumables: Sheets of crepe paper used to prevent the batch from getting wet (standard quantity of 20 sheets)
- Investment costs: Annual amortization of sterilizers in relation to the number of cycles per year
- Maintenance and qualification costs in relation to the number of cycles per year (except labor costs for Technical Services employees)

Determination of sterilizer capacity:

The total load volume is expressed in terms of standard baskets (30 x 30 x 60 cm/54 liters).

Determination of sterilizer volume indices:

This is done in two stages: The determination of the absolute volume of the basket and then the measurement of a correction factor explained in more detail below.

The absolute volume for the uro-digestive unit was determined by measuring the 3 dimensions of each treated product. In the case of individually packaged items, the measurements comprise the size of the pouch or tray used plus one centimeter in height to take into account the required space for the steam to pass through.

In more general terms, the goods must be arranged in a way that enables good steam penetration. The "useful" or "real" load volume is thus lower than the total load volume expressed as standard baskets (figure 3). Therefore, the use of the absolute product volume to calculate the volume indexes results in an underestimation of the costs of sterilization. To remedy this, product occupancy shall be expressed as a "corrected" volume, i.e. the absolute volume plus an applied "correction" volume.

![Fig. 3: Charge volumes](image)

This volume or correction factor was assessed during sterilizer loading on the basis of the volume not occupied by the goods in relation to the number of units in the batch. This measurement was taken for 10 full batches.

Data relating to washing costs

This function cannot presently be implemented in the manner initially intended at the University Hospital of Rouen since electronic traceability of washing services was not implemented yet. Thus, it was decided to attribute washing costs to each sterilized unit in a standard manner on the basis of the following formula:

\[ \frac{\text{Number of washing cycles per year} \times \text{average cost of washing cycle}}{\text{number of units sterilized and recorded on computer}} \]

The average cost of a washing cycle results from the average weighted by the number of cost items for the instrument washer-disinfectors and washing chamber cycle.
The operating costs for a washing cycle are as follows:

- Fluid costs: Electricity, water purified by reverse osmosis, and softened water used in 1 cycle
- Costs of consumables: Detergents and rinsing agents used for 1 cycle
- Investment costs: Annual amortization of washers in relation to the number of cycles per year
- Maintenance and qualification costs for washers and for the osmoser in relation to the number of cycles per year

Data relating to packaging

This function attributes costs for consumables associated with different types of packaging.

The process stages are as follows:

1. Identification of packaging types and associated consumables
2. Attribution of costs for passage indicator strip and adhesive tape as a standard rate: The billing of the passage indicator is based on a measurement of 15 cm; the billing of the adhesive tape is based on a measurement of 2 m.
3. Determination of the size of non-woven wrap used for each tray: Determined on the basis of the dimensions of each type of tray (1 tray type = 1 non-woven size)
4. Regarding double paper-plastic packaging: In view of the large number of reference products used and the technical constraints resulting from the software, we had to make certain billing decisions in order to reduce the types of consumable used as far as possible. For this reason, a single packaging has been taken into account, paper-plastic packaging trays, and an identical tray size for internal and external packaging. In addition, length and width intervals have been created.
5. Determination of costs of heat welding, broken down as follows:
   - Investment costs: Annual amortization in relation to number of individual instruments produced in 1 year
   - Annual maintenance costs in relation to the number of individual pouches produced in 1 year
   - Fluid costs: Electricity consumed by a welding operation
6. Regarding container packaging: The amortization of the cost of purchasing the container and the costs of maintenance and servicing have not been included since they are attributed to the budgets of the surgical units.

Data relating to handling costs

Definition of average hourly labor costs:

This is defined as the average cost of labor for each category of occupation, maintenance personnel, and supervisory staff weighted by the number of full-time equivalents for each of these categories. The cost per hour of one full-time equivalent is calculated on the basis of the salary in relation to hours actually worked.

Thus, the following data was collected:

1. Detailed list of personnel: Occupation category and number of full-time equivalents concerned
2. Hours actually worked by one full-time equivalent hospital worker (7 hours and 30 minutes per day; average absenteeism at the University Hospital of Rouen = 20 days) and one full-time equivalent medical occupation (eight hours per day; absenteeism considered to be zero) in accordance with the following formula:

\[
\text{[365 days – 104 days (weekends) – 10 days (public holidays) – 25 days (paid leave) – absenteeism]} \times \text{basic number of hours per day}
\]

3. Annual salary for each category of occupation (gross salary + employer contributions)

An average national salary cost is used for the salary costs of medical personnel. For hospital workers, the salary cost for each occupation category shall be calculated in accordance with the average adjusted index for the month of January. This index balances out the differences in levels of seniority that can exist within a single occupation category, thus avoiding age distribution effects.
Determination of handling times per product:

The only process step that varies depending on the product is the assembly of trays. For this reason, the handling time has been attributed in two parts: A common amount of time that is identical whatever the product and a specific amount of time taken to assemble the boxes, depending on the product packaging type (table I).

<table>
<thead>
<tr>
<th>TRAYS</th>
<th>CONTAINERS</th>
<th>Individual instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double non-woven</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembly time per product +</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time taken to wrap in double non-woven material</td>
<td>Time taken to place products in container</td>
<td>Time taken to package in double paper-plastic trays</td>
</tr>
</tbody>
</table>

**Tab. I: Specific activities and time requirements for each category**

The shared time comprises activities pertaining to item reception, washing, sterilization, distribution, the Bowie-Dick test, and facility upkeep. The specific handling time for each product as determined by its type - tray, individual instrument, or container - is added to this. All of the time measurements shall be stated in relation to a single production unit.

The assembly time was calculated with the help of the T-DOC software (average of 30 units for each type of tray) whereas the time devoted to other activities was timed internally by means of anonymized data capture carried out on all production for all units (table II).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Number of steps to be carried out</th>
<th>Min. number of actions to be timed</th>
<th>Key for unit division</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reception &amp; washing</td>
<td>15</td>
<td>5</td>
<td>Number of washing baskets</td>
</tr>
<tr>
<td>Validation of washing cycle parameters</td>
<td>20</td>
<td>5</td>
<td>Number of washing baskets</td>
</tr>
<tr>
<td>Removal of load from washing</td>
<td>15</td>
<td>3</td>
<td>Number of units in Batch</td>
</tr>
<tr>
<td>Preparation of sterilizer batch</td>
<td>15</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Validation of sterilization cycle and distribution parameters</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Container packaging</td>
<td>15</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Tray packaging</td>
<td>50</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Individual item packaging</td>
<td>50</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Tab. II: Timed activities and division keys**

*Data relating to cross-sector costs*

Certain costs that correspond to indirect/cross-sector expenditure are not yet taken into account. However, most of these are negligible when stated per unit. Thus, it was decided only to take into account the costs attributed to the purchase of the T-DOC software and costs relating to common expenditure into account. They are attributed on the basis of the annual amortization rate in relation to the number of annual units that are sterilized and registered in T-DOC.

With regard to the costs incurred through purchasing the software, in view of the amounts involved and despite completed amortization between 2004 and 2006, it was decided at the advice of the controlling department to include this cost in the production costs. The common costs comprise the amortization of the premises and furnishings and the costs of ensuring compliance.
Results

Data collection results

First of all, it is important to note that all cost data is exclusive of tax. With regard to usage costs, this value is always a multiple of EUR 0.04, which is the unit cost of an aluminum cup.

With regard to the cost of sterilization, the main parameter - namely the average cost of a sterilizer cycle - has been estimated at EUR 21.30. The breakdown of costs is presented in table III. Examples of sterilization costs for various products are illustrated in table IV.

### INVESTMENT COSTS

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual amortization (sterilizers and 6 probes used in them)</td>
<td>EUR 70,790</td>
</tr>
<tr>
<td>6 sterilizers (10-year amortization period)</td>
<td></td>
</tr>
<tr>
<td>6 Valivacq® probes (5-year amortization period)</td>
<td>EUR 5,166</td>
</tr>
<tr>
<td>Number of sterilization cycles carried out in 2008</td>
<td>8847</td>
</tr>
<tr>
<td></td>
<td>EUR 8.58</td>
</tr>
</tbody>
</table>

### MAINTENANCE COSTS

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance (spare parts; excluding Technical Services labor costs)</td>
<td>EUR 29,930</td>
</tr>
<tr>
<td>Annual operational qualification checks</td>
<td>EUR 6,000</td>
</tr>
<tr>
<td>Number of sterilization cycles carried out in 2008</td>
<td>8847</td>
</tr>
<tr>
<td></td>
<td>EUR 4.06</td>
</tr>
</tbody>
</table>

### FLUID COSTS

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softened water</td>
<td>EUR 0.70</td>
</tr>
<tr>
<td>350 liters</td>
<td></td>
</tr>
<tr>
<td>Cost per m³: EUR 2</td>
<td></td>
</tr>
<tr>
<td>Water purified by reverse osmosis</td>
<td>EUR 0.07</td>
</tr>
<tr>
<td>20 liters</td>
<td></td>
</tr>
<tr>
<td>Cost per m³: EUR 3.5</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>EUR 4.37</td>
</tr>
<tr>
<td>40kWh x 1h 30</td>
<td></td>
</tr>
<tr>
<td>Cost per kWh: EUR 0.0729</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EUR 5.14</td>
</tr>
</tbody>
</table>

### COST OF CONSUMABLES

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheets of crepe paper (standard quantity: 20 sheets)</td>
<td>EUR 3.52</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| TOTAL COST                                                                  | EUR 21.30 |

### Tab. III: Average cost of a sterilization cycle

<table>
<thead>
<tr>
<th>Name of product (number of instruments)</th>
<th>Length (cm)</th>
<th>Breadth (cm)</th>
<th>Height (cm)</th>
<th>Abs. vol. (liters)</th>
<th>Corr. vol. (liters)</th>
<th>Volume (number of baskets)</th>
<th>Sterilizer volume index</th>
<th>Sterilization cost (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall (17) (non-woven)</td>
<td>24</td>
<td>14</td>
<td>4.5</td>
<td>1.51</td>
<td>3.96</td>
<td>0.07</td>
<td>13.63</td>
<td>0.25</td>
</tr>
<tr>
<td>Optical basket for coelio (2) (non-woven)</td>
<td>46</td>
<td>8</td>
<td>6</td>
<td>2.21</td>
<td>4.66</td>
<td>0.09</td>
<td>11.59</td>
<td>0.29</td>
</tr>
<tr>
<td>Abdominal (78) (container)</td>
<td>60</td>
<td>30</td>
<td>16</td>
<td>28.8</td>
<td>31.25</td>
<td>0.58</td>
<td>1.73</td>
<td>1.97</td>
</tr>
<tr>
<td>Coelio (41) (container)</td>
<td>60</td>
<td>30</td>
<td>13.5</td>
<td>24.3</td>
<td>26.75</td>
<td>0.50</td>
<td>2.02</td>
<td>1.69</td>
</tr>
<tr>
<td>Liver retractor (individual)</td>
<td>81</td>
<td>16</td>
<td>4.5</td>
<td>5.83</td>
<td>8.28</td>
<td>0.15</td>
<td>6.52</td>
<td>0.52</td>
</tr>
<tr>
<td>Curved-blade Mayo scissors, 17 cm (individual)</td>
<td>40</td>
<td>12</td>
<td>2.5</td>
<td>1.2</td>
<td>3.65</td>
<td>0.07</td>
<td>14.79</td>
<td>0.23</td>
</tr>
</tbody>
</table>

### Tab. IV: Examples of sterilization costs
### Activity | Time per unit
--- | ---
Common handling time | 
Reception & washing | 2 minutes 47 seconds
Validation of washing cycle parameters | 3 seconds
Removal of load from washing | 46 seconds
Preparation of sterilizer batch | 38 seconds
Distribution | 48 seconds
Upkeep | 34 seconds
Bowie-Dick test | 3 seconds
Total | 5 minutes 40 seconds

### Specific handling time

Packing into containers | 1 minutes 30 seconds
Packing in double non-woven wrap | 3 minutes 23 seconds
Packing as individual units | 1 minutes 7 seconds
Assembly time for each type of tray | See Annex 7

**Tab. V: Common and specific handling times**

The average cost of a washing cycle has been estimated as EUR 11.23. Bearing in mind that 12,038 washing cycles took place in 2008, the flat-rate washing cost is EUR 0.69 per unit.

The cost of packaging in double non-woven wrap is between EUR 0.48 and EUR 1.66 depending on the size of wrap used. With regard to paper-plastic packaging, the cost of a heat weld has been estimated as EUR 0.014. The overall cost of this type of packaging is between EUR 0.11 and EUR 0.50 depending on the sizes used. Finally, the cost of packaging in a container is EUR 0.02.

With regard to handling costs, the average hourly personnel rate is EUR 24.87. The common and specific handling times are shown in table V. Table VI illustrates certain examples of handling costs on the basis of this data. With regard to cross-sector costs, the software costs amount to EUR 0.54 per unit and common expenditure amounts to EUR 0.56 per unit (table VII).

### Table VI: Examples of handling costs

<table>
<thead>
<tr>
<th>Name of product (number of instruments)</th>
<th>Common handling time</th>
<th>Assembly time</th>
<th>Packing time</th>
<th>Total handling time</th>
<th>Cost of handling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall (non-woven) (17)</td>
<td>5 min 40 s</td>
<td>2 min 50 s</td>
<td>3 min 23 s</td>
<td>11 min 53 s</td>
<td>EUR 4.93</td>
</tr>
<tr>
<td>Optical basket for coeliosurgery (non-woven) (2)</td>
<td></td>
<td>26 s</td>
<td></td>
<td>9 min 30 s</td>
<td>EUR 3.94</td>
</tr>
<tr>
<td>Coelio (41) (container)</td>
<td>14 min 50 s</td>
<td>1 min 30 s</td>
<td></td>
<td>22 min 02 s</td>
<td>EUR 9.13</td>
</tr>
<tr>
<td>Abdominal (78) (container)</td>
<td>21 min 05 s</td>
<td></td>
<td>1 min 07 s</td>
<td>30 min 09 s</td>
<td>EUR 11.71</td>
</tr>
<tr>
<td>Individual instruments</td>
<td></td>
<td></td>
<td></td>
<td>6 min 47 s</td>
<td>EUR 2.81</td>
</tr>
</tbody>
</table>

**Tab. VI: Examples of handling costs**
**Annual amortizations: (10-year amortization period)**

<table>
<thead>
<tr>
<th>Costs</th>
<th>Cost (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs of ensuring compliance</td>
<td>31,229</td>
</tr>
<tr>
<td>Furniture/buildings</td>
<td>936,371</td>
</tr>
<tr>
<td>General installations, layout, facilities</td>
<td>71,285</td>
</tr>
<tr>
<td><strong>TOTAL COST</strong></td>
<td><strong>108,494</strong></td>
</tr>
<tr>
<td>Number of units sterilized and registered in T-DOC in 2008</td>
<td>193,740</td>
</tr>
<tr>
<td><strong>COST PER UNIT</strong></td>
<td><strong>0.56</strong></td>
</tr>
</tbody>
</table>

**Tab. VII: Breakdown of common costs**

**Total cost of sterilization process**

**By tray type**

The total cost of the sterilization process for each type of tray in double non-woven wrap (104 types) and in containers (15 tray types) is illustrated by means of the scatter diagram in figure 4. Each point on the graph corresponds to a type of tray; the position of the point represents the cost of sterilization. Thus, this graphic exemplifies the differences in cost that can exist between different types of tray used by the uro-digestive surgical unit.

The two main parameters responsible for the total cost variation of the sterilization process for trays are volume (as shown in figure 5) and handling time (related to assembly time and the number of instruments in each type of tray - shown in figure 6). Figure 5, which shows the cost variation between the tray types for the cost of sterilization only, and figure 6, which shows the cost variations due to the number of instruments in each tray, follow the same principle as the scatter diagram in figure 4.

**Fig. 4:** Total cost of sterilization process by tray type

**Fig. 5:** Cost of sterilization by tray type

**Fig. 6:** Cost of handling trays in relation to number instrument type

**Fig. 7:** Total cost of sterilization process by individual of instruments per tray
By individual instrument type

Unlike for trays, the total cost for individual instruments can only really be influenced by their volume; the costs of packaging remain negligible. Figure 7 follows the same principle as the preceding scatter diagrams and illustrates the fact that the total cost of the sterilization process for a large majority of individual instruments is around EUR 5. The cost of sterilization can thus be fixed at EUR 5 for all individual instruments in the tray of a subsequent study regarding their handling or billing. Examples of total costs per tray type or individual instrument type are presented in table VIII.

<table>
<thead>
<tr>
<th>Name of product (number of instruments)</th>
<th>Cost of usage</th>
<th>Cost of sterilization</th>
<th>Cost of washing</th>
<th>Cost of packaging</th>
<th>Cost of handling</th>
<th>Common expenditure + cost of software</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall (non-woven) (17)</td>
<td>EUR 0.04</td>
<td>EUR 0.25</td>
<td>EUR 0.48</td>
<td>EUR 4.93</td>
<td>EUR 0.56</td>
<td>EUR 0.54</td>
<td>EUR 7.49</td>
</tr>
<tr>
<td>Optical basket for coeliosurgery (non-woven) (2)</td>
<td>EUR 0.29</td>
<td>EUR 0.96</td>
<td>EUR 0.96</td>
<td>EUR 3.94</td>
<td>EUR 12.67</td>
<td>EUR 0.56 + EUR 0.54</td>
<td>EUR 6.98</td>
</tr>
<tr>
<td>Coelio (41) (container)</td>
<td>EUR 0.04</td>
<td>EUR 1.69</td>
<td>EUR 0.02</td>
<td>EUR 9.13</td>
<td>EUR 15.53</td>
<td>EUR 0.56</td>
<td>EUR 12.67</td>
</tr>
<tr>
<td>Abdominal (78) (container)</td>
<td>EUR 0.04</td>
<td>EUR 1.97</td>
<td>EUR 0.02</td>
<td>EUR 11.71</td>
<td>EUR 15.53</td>
<td>EUR 12.67</td>
<td>EUR 5.41</td>
</tr>
<tr>
<td>Liver retractor (individual)</td>
<td>EUR 0.52</td>
<td>EUR 0.96</td>
<td>EUR 0.29</td>
<td>EUR 2.81</td>
<td>EUR 15.53</td>
<td>EUR 0.56</td>
<td>EUR 4.95</td>
</tr>
<tr>
<td>Curved-blade Mayo scissors, 17 cm (individual)</td>
<td>EUR 0.23</td>
<td>EUR 0.12</td>
<td>EUR 0.12</td>
<td>EUR 2.81</td>
<td>EUR 15.53</td>
<td>EUR 0.56</td>
<td>EUR 4.95</td>
</tr>
</tbody>
</table>

Tab. VIII: Examples of total cost of sterilization process (EUR)

Data exploitation

Figures 8 and 9 illustrate the breakdown of sterilization process costs over the various cost categories. Annual sterilization services for the uro-digestive unit have been estimated at EUR 412,252 (excluding taxes). This estimation is derived from the total cost of the units sterilized during a single day extrapolated for 261 productive days. An example of a billing report is shown in figure 10.

Fig. 8: Breakdown of sterilization process costs for trays
Now that the parameterizations and data definitions have been effected for the uro-digestive unit, the approximate total time required to incorporate a new unit can be estimated at 26 hours and 30 minutes. This breaks down as follows: 1 hour and 30 minutes to compile the list of goods, 6 hours to measure the three dimensions of each product, 7 hours to determine the average assembly time for the trays, 5 hours for data processing, and 7 hours to enter the data into T-DOC. Furthermore, for the purposes of suggesting a cost for a material to be contracted out, a base time of 17 seconds per instrument can be used to determine the assembly times. (This is the average time gleaned from the data on the goods of the uro-digestive unit.)

Proposal for a simplified cost calculation method

With respect to the information collected during the course of the study, it is possible to derive a simplified cost calculation method that can be used even without the T-DOC software and without any sort of electronic process traceability - a cost calculation method for a tray or instrument whatever type of traceability is used (see table IX).
<table>
<thead>
<tr>
<th>Type of cost</th>
<th>Means of determination</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Usage costs</strong></td>
<td></td>
</tr>
<tr>
<td>· Determination of the list of consumables used to make up the trays</td>
<td>Flat rate</td>
</tr>
<tr>
<td>· Investigation into prices per unit and annual consumption</td>
<td>Annual costs/number of units produced per year</td>
</tr>
<tr>
<td><strong>Packaging costs</strong></td>
<td></td>
</tr>
<tr>
<td>· Determination of the list of packaging consumables</td>
<td>Flat rate</td>
</tr>
<tr>
<td>· Investigation into prices per unit and annual consumption</td>
<td>Annual costs/number of units produced per year</td>
</tr>
<tr>
<td><strong>Washing costs</strong></td>
<td></td>
</tr>
<tr>
<td>· Determination of the average cost of a washing cycle</td>
<td>Flat rate</td>
</tr>
<tr>
<td><strong>Sterilization costs</strong></td>
<td></td>
</tr>
<tr>
<td>For all sterilizers:</td>
<td></td>
</tr>
<tr>
<td>· Determination of average cycle costs</td>
<td>Depends on the product</td>
</tr>
<tr>
<td>· Determination of average capacity in terms of standardized baskets</td>
<td>(Average cost of cycle/average capacity in standardized baskets)/ sterilizer volume index</td>
</tr>
<tr>
<td>For each product:</td>
<td></td>
</tr>
<tr>
<td>· Determination of sterilizer volume index</td>
<td></td>
</tr>
<tr>
<td><strong>Handling costs</strong></td>
<td></td>
</tr>
<tr>
<td>· Determination of average hourly labor costs</td>
<td>Depends on the product</td>
</tr>
<tr>
<td>· Determination of number of instruments for each type of tray</td>
<td></td>
</tr>
<tr>
<td><strong>Timing</strong></td>
<td></td>
</tr>
<tr>
<td>· Determination of assembly time per instrument</td>
<td>([Number of instruments x assembly time] + other handling time) x hourly rate</td>
</tr>
<tr>
<td>· Determination of common and specific times</td>
<td></td>
</tr>
<tr>
<td><strong>Cross-sector expenditure</strong></td>
<td></td>
</tr>
<tr>
<td>To be determined as per specific establishment conditions</td>
<td>Flat rate</td>
</tr>
</tbody>
</table>

**Tab. IX: Simplified cost calculation method**

The main approximations will deal with the costs of usage and packaging, which can be attributed as standard flat-rate values for every single product; the variations seen in these two types of cost are minimal.

The handling costs and sterilizer volume - which are major factors in the variation of process costs - are not approximated. The method to be used shall be identical but it will nevertheless be necessary to determine the instrument assembly time. The assembly time can vary significantly - both in the same person and between two people - and thus the number of measurements to be taken must be at least 30.

**Discussion**

**Benefits**

The main advantage of this method is that sterilization costs are determined for each individual product in relation to the volume used in the sterilizer, the time required for handling, and the type of packaging. The results show that the combination of these parameters significantly influences the product costs for trays, which vary between EUR 6.15 and EUR 14.79; the costs for individual instruments remain in a range of EUR 4.82 to EUR 5.86. Indeed, for the latter products the handling time is fixed and the cost variations arising from their volume (between EUR 0.11 and EUR 1.09) and packaging (between EUR 0.11 and EUR 0.39) remain small.

The method of determining costs for each product comes into its own when applied to trays, since here the differences between the number of instruments in a tray and their volume are considerable. The assembly times range from 11 seconds (cost = EUR 0.08) to 21 minutes and 5 seconds (cost = EUR 8.74). Packaging is also a factor that must be taken into account, since placing instruments into a container reduces costs both in terms of material (EUR 0.02 for a fork in comparison with EUR 0.48 to EUR 1.66 in non-woven depending on the size of double non-woven used) and in terms of handling (90 seconds for a cost of EUR 0.62 in a container and 203 seconds for a cost of EUR 1.40 in non-woven).

Thus, in view of the data, it makes sense to determine a sterilization cost for each product. Indeed, the cost per m³ of sterilized goods arising from the four cost accounting groups is subject to various restrictions, both in its structure and its
ability to accurately reflect the complexity of the overall sterilization process (14). The two parameters on which it is
based are subject to various biases:

The number of annual cycles can be overestimated by the inclusion of daily mandatory cycles that are carried out in
order to conduct the Bowie-Dick test and by the inclusion of empty maintenance cycles. The number of annual cycles
would not have any significance at all if not taken in conjunction with the capacity of the sterilizers, which is subject to
bias depending on how it is expressed: As a total tank volume in liters, load volume of standard baskets, or useful
volume. Finally, this capacity does not tell us anything about the composition of the load in terms of products, e.g.
several low-volume ophthalmology trays or a few large-volume orthopedic trays, or about the way in which the load is
processed (fill level of the sterilizer). Thus, if we stick to costs per m³, it is impossible to determine a cost per product for
the actual sterilization process itself, since this will remain variable depending on the changing nature of the other
products in the same batch as per current sterilization activities. To sum up, the cost per m³ does not reflect deviations
relating to essential activities that could have a significant effect on costs, namely the costs of washing, packaging, and
above all - assembly. Thus, this cost evaluation - which is both specific to individual products and takes into account
costs as they arise along the process chain, namely as a result of activities that make up the process - is similar to
recently developed methods that are increasingly used in hospitals, such as the method proposed by Steriprocess (12)
and the ABC/ABM (Activity-Based Management/Activity-Based Costing) method (1, 4, 7, 11, 16, 17).

The determination of costs per product therefore appears more appropriate for all billing activities, whether they be
contracted internally (13) or subcontracted to third parties. To date, sterilization expenses have been attributed in the
form of a global flat rate and appear indirectly in the medical technology lines of the centre management table. In the
case of subcontracting, the specification of costs per product would optimize customer/supplier relationships. Instead of a
global flat rate in relation to the sterilized volume (9), billing would be based on exactly the sterilization services rendered.
Moreover, it is important to incorporate the costs for each product into this evaluation approach in order to be able to
satisfactorily comply with subcontracting tender requirements, which are increasingly formulated in terms of work units
(e.g. pouches, trays, and container types) and to compete with private subcontracting bids, where the tendency is
already to bill per unit (5). Finally, the determination of costs per product enables the refining of new purchasing
strategies with regard to single-use material versus re-sterilizable goods with a view to switching towards economically
attractive options of single-use instruments (15, 18).

Furthermore, this two-fold costing process - on the basis of costs per product and in terms of costs per process stage -
supports the hospital pharmacist in running sterilization activities and more effectively makes the surgical department
aware of the costs of sterilization. Improving budget management would constitute an argument with regard to certain
optimization issues: Reducing the use of individual instruments, standardizing the composition of trays, or improving the
management of out-of-date items. In addition, the possibility of increasing costs for processing goods urgently or for non-
compliant instruments (poorly pre-disinfected, instruments that are missing at the assembly stage etc.) could be
considered. This cost management tool therefore also helps to improve quality and thus the services rendered to the
patient.

Lastly, it is important to point out that the determination of costs per product is greatly facilitated by the T-DOC software.
This software brings about many advantages with regard to calculation automation, fast cost updates, and the provision
of detailed billing reports.

Limitations

In general, it is important to remember that the sterilization process groups together a range of activities and that each of
these activities has aspects that are both complex to differing extents and diverse. Thus, their quantification requires
certain approximations to be made; and these approximations simply cannot take into account all of the variations that
are seen in practice. This is partly due to the wide variety of surgical goods to be processed and to the fact that activity
depends on the activities of the surgical units in question, and is thus subject to fluctuations.

In more specific terms, the main limitations of this study relate to the attribution of washing costs, sterilization costs, and
handling times. With regard to washing, the flat rate used does not reflect the true diversity of the activities that take
place. Since it is applied without distinction to all products, the flat rate levels out the cost of washing across all
processed goods. In fact, the washing costs for a tray far exceed the cost of washing an individual instrument. The
volume occupied by an individual instrument in a washer is less than that taken up by instruments in a tray which
depending on their type - may be distributed among multiple washing baskets. Furthermore, depending on the type of
goods and tray packaging type, other washing cycles may have to be carried out: Washing the tray, washing the
container, and washing instruments requiring irrigation. In addition, manual washing and certain complementary
processes such as ultrasound have not been taken into account.

With regard to the sterilization costs, the main bias is the application of an identical correction factor to each product type
(i.e. individual instruments, trays in non-woven, and trays in a container). The costs of sterilizing individual instruments
are thus slightly overestimated and the costs of sterilizing trays slightly underestimated. However, the application of
different factors would have made the scope of the study too complex.

With regard to handling times, theses times only take into account the effective time for handling a product and not
related supplementary times such as the following:
- Time spent solving various problems: Instruments that need to be rewashed, instruments that are missing at the assembly stage, production control, machinery breakdowns, power cuts etc.
- Time spent on handover from/to the surgical units

Although these times are not negligible, they are difficult to quantify.

Lastly, this method is still not extensively developed and cannot be applied at present. In effect, the cost per sterilized cubic meter remains the reference work unit for calculating the costs published in external benchmarks such as the "Base d'Angers" and ENC (National Costs Study) indicators.

**Difficulties encountered**

Similarly, the technical difficulties relating to the software have not yet been solved. The other difficulties encountered were those traditionally encountered in cost studies, namely problems relating to the definition of data to be taken into account and the integration limits for certain cost types (10).

**Difficulties relating to the definition of parameters**

The "handling time" parameter gave rise to numerous questions regarding its definition and measurement. Different methods were addressed but then rejected since they produced excessive results that included "dead" time when no real handling took place by personnel (e.g. the amount of time trays sit waiting to be assembled, packaged, or loaded).

The incorporation of cross-sector expenditure into the study also gave rise to certain questions: Which of these expenditure items should be included in the cost? Where should we stop with the regard to the attribution of these costs? How can we retrieve accurate data from the cost accounting budget accounts, which are quite removed from the activities being investigated?

Finally, the question of whether or not the goods are fully amortized arises from the incorporation of investment costs. It was decided to fully attribute costs in the tray of the main units (sterilizers and software), which are completely amortized and thus no longer figure in accounting processing, to take into account the retention of a "use value". This has been expressed as the annual amortization value, which represents the maximum attributable value.

**Difficulties relating to the collection of data**

In general, this proved itself to be very time-consuming. It gives rise to certain questions: Who holds the correct information? Where is the source information? What is the structure for calculating the supplied figures?

**Future steps**

It would be interesting to apply the same methodology to other surgical units since the results of such studies would enable points of comparison and supplementary analyses. A billing system to be incorporated into inter-center contracting could be implemented and then - in a second stage - sterilization services could be billed per patient and operation as part of the "pricing by activity" (T2A) framework. Moreover, another option - and a real economic issue - would be to use this method to define price offerings most appropriate for the goods to be sterilized for the purposes of subcontracting markets.

Lastly, certain technical points that have not been discussed in detail here might be developed. Notably, this includes the billing of washing services and invoicing reports (addition of one line each for VAT and financing costs and addition of various headings etc.).

**Conclusion**

The use of the T-DOC traceability software has enabled the specific determination of sterilization costs for each product. This new approach to the structure of costs enables a more accurate accounting overview for real activities in each surgical unit than that provided by analytical cost accounting. For hospital pharmacists, being aware of costs per product and per process stage is both useful for the management of costs and for improving quality and thus services rendered to the patient. There are also new possibilities with regard to subcontracting (the creation of a tool to support strategic decisions by the management), internal contracting, and - in the long term - billing by patient and operation.

Moreover, since the method and its application are also feasible for use in other health establishments, the definition of new external benchmarks for the comparison of activity costs can be envisaged. At present, the benchmark used by the ENC, which is used to compile the prices of the homogenous hospital stay groups (GHS), is still the cost per cubic meter resulting from analytical cost accounting. This is not particularly representative of the real costs.

To conclude, the information on costs per product resulting from this method will enable the pricing of the sterilization process for the surgical units and also for the managing entities of health establishments.
Bibliography


5. Laurent P., Le CHU de Caen passe à la soustraitance Omasa, Stérilisation Magazine No. 60 – April/May 2008


9. J.C. Chastant, Accord de partenariat entre Sterience et Générale de Santé, Stérilisation Magazine no. 48, April/May 2006

10. J. Husson, La stérilisation combien ça coute, Workgroup 1 CEFH, Nantes 2004


15. Secq A., Vantyghem C., Dubaele JM., Dispositifs médicaux stériles à usage unique ou réutilisables: Study sponsored by the University Hospital of Amiens, Europharmat, 19èmes journées nationales d’études sur les dispositifs médicaux (19th National Congress on Research into Medical Devices), Strasbourg 2009


17. Sechet E., Tiphine T., Evaluation du coût d’une prestation de stérilisation en 2006 par la méthode ABC, APHO Congress

