Injectomat versus Infusomat in Day Surgery. A prospective, mixed-methods observational project, investigating which procedure is most sustainable

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Abstract

Background: Anaesthesia procedures can impact both environmental sustainability and the physical health of healthcare professionals. At Aarhus University hospitals Day Surgery Department, nurse anaesthetists reported finger pain and discomfort associated with frequent manual syringe preparation using injectomat. The aim was to compare the environmental impact, cost, and ergonomic workflow of two anaesthesia delivery procedures: injectomat (syringe pumps) or infusomat (drop counters).

Method: We conducted a prospective, mixed-method observational study over 16 weeks, to investigate the difference of the two anaesthesia procedures. Anaesthesia nurse (n = 22) alternated between using injectomat and infusomat in two 8 week periods. Quantitative data were collected via daily utensil logs and the Disabilities of the arms, shoulders and hands questionnaire at weeks 1, 4, and 8 of each period. Life Cycle Assessment was used to calculate the CO_{2e} emissions of the utensils involved. Semi-structured interviews were conducted for qualitative insight.

Results: Using infusomat reduced the daily amount of utensil used by 41,6%, resulting in a 13,6% cost reduction and a 33,42% decrease in CO_{2e} emissions. Disabilities of the arms, shoulders and hands scores improved by 25,97% in week 1, 12,8% in week 4, and 25% in week 8 during the infusomat period. Interviewed nurse anaesthetists reported significantly less strain on hands and fingers.

Conclusion: Infusomat offer a more sustainable alternative to injectomat in anaesthesia for short procedures. They reduce utensil consumption, lower CO_{2e} emissions, and improve nurse anaesthetists' physical comfort. Further research is recommended in settings with longer procedures to assess generalizability and long-term effects.

Keywords: anaesthesia, Carbon footprint, cost- effectiveness, sustainability, work environment.

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Introduction

Approximately 10,000 patients undergo surgery each year at the Day Surgery Department, Aarhus University Hospital, Denmark. This department covers a range of surgical specialties, including gastroenterology, orthopaedic, gynaecology, urology, neurology and ear, nose and throat surgery. To facilitate these surgeries, most patients are placed under general anaesthesia. Some patients receive general anaesthesia combined with a regional block, while a few short interventions are performed in local anaesthesia. In our department, propofol and remifentanil are the primary medical agents used for the anaesthesia.

The idea behind the study originated from reports by anaesthesia nurses who experienced significant finger pain and stiffness, in some cases from bending their fingers. Combined with the global focus on climate change, which is the biggest threat towards the global health, motivated us to explore ways to address both ergonomics and environmental concerns (1). Hospitals emit large quantities of carbon dioxide (CO_2 emissions), leading to increasing international consensus documents advocating for the reduction of utensil use, medication waste, and general hospital waste (2, 3).

This study evaluates an alternative procedure for administering anaesthesia medications with consideration for environment, workflow, and cost. Traditionally, anaesthesia medications are delivered using syringe pumps (Injectomat). In this study, we tested the use of drop counters (Infusomat) as an alternative.

To our knowledge, only one study has previously investigated the reuse of utensils in surgical settings, and it did not involve infusomat. Karlsson et al. tested the reuse of syringes between patients and found no significant risk of bacterial contamination (4). An older study also reported no contamination risk when using two anti-reflux valves (5). However, it is important to note that while the pharmaceutical companies recommend single use for the syringe and drop set, hospital specific protocols, if approved by the medical management and hospital's infection control nurse, may already allow reuse of syringes for injectomat (6). Implementing the infusomat procedure would similarly require the creation and approval of a new reuse protocol for the infusomat drop sets.

This study aimed therefore to evaluate and compare the two procedures with respect to ergonomic workflow impact on the hands, fingers, elbows, and shoulders, the consumption and cost of medical utensils, and to investigate which procedure was more sustainable from an environmental perspective measured in CO_2 emissions.

Materials and Methods

The study was conducted at the Day Surgery Department, Aarhus University Hospital (AUH), Denmark, between mid-August 2024 and March 2025. Prior to the study initiation, the nurse responsible for clinical development held an information meeting for all staff involved. This meeting provided details about the objectives and

procedures, and distributed project folders containing relevant information.

To introduce the infusomat, the anaesthesia nurses received training on their use from a representative of the pharmaceutical company supplying the infusomat.

Inclusion
All anaesthesia nurses and anaesthesia nurse students employed at the Day Surgery Department, AUH, was invited to participate.

Exclusion
All anaesthesia doctors were excluded from the study, as medication preparation is not a primary component of their primary responsibilities.

The two procedures
Using either one of the procedures we change the intravenous drop set and the double barrelled medical kit, also called the double run Total Intravenous Anaesthesia set (TIVA set), between every patient. Therefore, no counting concerning that. But the rest of the utensils varied according to which procedure was in use (Figure 1).

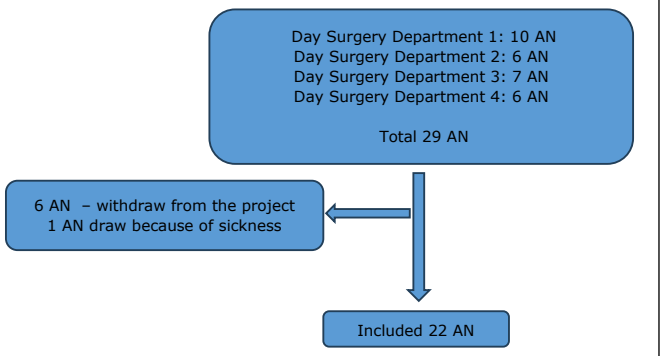

Figure 1. Flowchart of the inclusion of the anaesthesia nurses .

Injectomats
The injectomats are the most traditionally procedure used, and the 60 ml syringes for the injectomats are manually drawn by the anaesthesia nurse, for the anaesthesia medications (propofol and remifentanil). When a syringe empties, an alarm sounds and a new syringe must be drawn up and attached. These syringes are then loaded into the Injectomats. This manual, repetitive syringe filling process is physically demanding and places significant strain on the hands and fingers of the nurses. Our department don't have prefilled syringes so all filling is carried out manually by the anaesthesia nurse.

Infusomats
When using infusomat, anaesthesia medications are prepared by connecting medication bottles to a drop set that is attached to the infusomat. This setup is prepared in the morning during the surgery room setup. During the day, when a bottle empties, the anaesthesia nurse simply replaces it by attaching a new bottle to the existing drop set. This method eliminates the need for manually drawing up medications into syringes, thereby potentially reducing strain on the hands and fingers and decreasing the consumption of single use utensils. If correct hygiene protocols are observed, the same drop set may be used for up to eight hours (7, 8).

Study Design
A prospective mixed method observational study was conducted over 16 weeks.

To evaluate which procedure provided the most ergonomic workflow, the study was divided into two consecutive eight week periods. During the first period, anaesthesia nurses used injectomat as the traditional method. Following the introductory training, the anaesthesia nurses switched to using infusomat for the subsequent eight weeks. Throughout the full 16 weeks, participants completed two types of schedules and questionnaires, which were stored in individual project folders. Finally, to each eight week period, a semi structured focus group interview was conducted by a work environment representative.

The ergonomic workflow
To examine the ergonomic workflow, we used the questionnaire "Disabilities of the arms, shoulders and hands" (DASH), validated in Danish (9). The DASH questionnaire was developed in 1996 by the American Association of Orthopaedic Surgery (AAOS) and the Institute for Work & Health (Toronto)(10). It is a validated, sensitive and reliable questionnaire, shown to be quick and easy to answer (11).

It is a self-reported questionnaire with 30 items, each with five possible answers. The 30 questions are divided into: 21 of questions concern the functionality of daily living activities; 5 questions specifically concerns symptoms as pain, weakness, stiffness and sensitivity and the last four questions covers professional and social activities (10, 12).

For calculating the DASH score a mathematical formula is used. The score extends from 0-100; 0 is no disabilities and 100 is maximum disability (11).

The anaesthesia nurses scored the DASH three times during both the injectomat and the infusomat period; 1. week, 4. week and 8. week, in total 6 times.

Qualitative Interviews
Focus group interviews was conducted to get a description of the anaesthesia nurses ergonomic workflow using the two procedures, and if and how the two procedures affects their hands, fingers or shoulders. A work environment representative conducted the interviews and the analysis.

Usage of utensils and sustainability
To record the use of utensils, and thereby the carbon footprint, associated with the two procedures, we developed a registration schedule, where the anaesthesia nurses registered their daily use of utensils, during both periods.

The Centre for Sustainable Hospitals calculated the Life Cycle Assessment (LCA) for each utensil. LCA is a method used to evaluate the environmental impact and resource consumption associated with products or services. This comparative study is calculated by CO_{2e} emissions and with a cradle-to-grave approach which includes the stages from raw material extraction to disposal (13).

Pricing information for each utensil was obtained from the Aarhus University Hospital purchasing department as of June 2024 and is presented in Danish kroner (DKK). To respect confidentiality agreements with medical suppliers, only the total costs are reported. Prices are listed in table 1 based on March 2023 rates (Table 1).

Analysis
The manual utensil schedules and the DASH scores were collected after the 16 weeks. The total and average usage of utensils, along with the DASH scores, were calculated and analysed.

Ethical Approval
Ethical approval for this study was not required because, it does not involve experiments on humans or animals. The investigation of the new work-related procedure falls outside the Ethical Committees jurisdiction.

Table 1. The utensils used to start up the day for either the injectomat and the infusomat.

Injectomat			Infusomat			
Number	DKK	CO_{2e}	Utensils	Number	DKK	CO_{2e}
2	-	384,7	60 ml syringes	0	-	-
2	-	88,6	Spike	0	-	-
1	-	51,9	Anti reflux valves	1	-	51,9
1	-	104,5	Transfer needle	1	-	104,5
0	-	-	Infusomat drop set	2	-	416,6 (long)-341,5 (short)
6	32,97	1103	Total	4	40,69	989,6 (long) – 839,4 (short)

Results

A total of 22 the anaesthesia nurses participated in the study. Initially, 29 the anaesthesia nurses were enrolled; 6 withdrew due to difficulties with the infusomat, 1 never got started registering because of sickness. So, we ended up with 22 anaesthesia nurses for analysis (Figure 1).

The ergonomic work flow

The overall results from the DASH score showed a clear tendency towards improved ergonomic work flow when using Infusomats instead of Injectomats.

However, only 7 out of the 22 anaesthesia nurses completed the DASH questionnaire at all six times. Therefore, instead of calculating a total score, we calculated the average scores for those anaesthesia nurses who completed the questionnaire at the same time points during each period. During both procedures 10 anaesthesia nurses had scores the 1st-week; 12 the anaesthesia nurses had scored the 4th- week and 10 anaesthesia nurses had scored the 8th.

Compared the anaesthesia nurses scored (Table 2):

The 1st week 7,7 (injectomat) and 5,7 (infusomat)

The 4th week 7,8 (injectomat) and 6,9 (infusomat)

The 8th week 6,8 (injectomat) and 5,1 (infusomat)

This corresponds to a **25,97 % reduction** in the DASH score at the 1st-week scoring when comparing the infusomat period to the injectomat period.

At the 4th-week scoring, a **12,8 % reduction** was observed, and by the 8th week, the DASH score showed a **25 % reduction** after the anaesthesia nurses had switched from injectomat to infusomat (Figure 2).

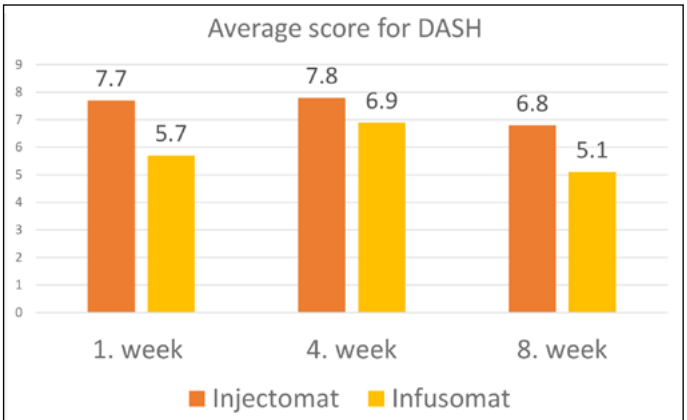

Figure 2. The DASH average results compared for the injectomat and the infusomat period.

Interview results

A total of 11 anaesthesia nurses participated in the interview following the injectomat period, and 5 anaesthesia nurses participated in the interview after the infusomat period.

In response to the question **"What are your ergonomic challenges when using the injectomat?"**, the anaesthesia nurses, after 8 weeks of using the injectomat, reported:

- *"Pain in my thumb, all the way into my hand."*
- *"It is hard to pull up the syringes."*
- *"No pain, but I can feel that it loads up, particularly in the thumb."*

When asked the same question after 8 weeks of using the Infusomats, the anaesthesia nurses responded:

Table 3. The results of the used amount of utensils during the injectomat and the infusomat period.

	Injectomat (n= 345)				Infusomat (n =339)		
Utensils	Amount	Price	CO_{2e}	Utensils	Amount	Price	CO_{2e}
60 ml Syringes	1926	3967,56	323568	60 ml Syringe	90	185,4	15120
Spike	1216	12001,92	94604,8	Spike	288	2842,56	22406,4
Anti reflux valves	1010	3151,2	23634	Anti reflux valves	1.168	3644,16	27331,2
Transfer needle	830	4971,7	80676	Transfer needle	708	4240,92	68847,6
Infusomat drop set	0	0	0	Infusomat drop set	604	9537,16	208133,4
Total	4982	24092,38	522482,8	Total	2858	20450,2	341838,6
Pr. patient	**14,44**	**69,83**	**1.514,44**	**Pr. patient**	**8,43**	**60,33**	**1.008,37**
Percentage difference				**Percentage difference**	**-41,6%**	**-13,6%**	**-33,42%**

Table 2. The DASH scoring for the AN for both the injectomat and the infusomat period.

	Injectomat			**Infusomat**			
Nurse	1.	2.	3.	Nurse	1.	2.	3.
a.	8,62	3,45	12,07	a.		6,9	5,17
b.				b.			
c.	6,89	6,03	12,06	c.	5,17	6,89	4,31
d.				d.	0	0	0
e.	18,1			e.	0		
g.	3,45		2,58	g.			
h.	0	0,89	0,86	h.	0,86	0,86	0
i.	0	1,72	0	i.		0	0
j.	12,93	17,24	26,72	j.	35,34	20,7	14,66
k.				k.			
l.		6,8	5,17	l.		1,72	4,31
m.	0,86	0	0	m.	0	0	18,75
n.	21,55			n.			
o.				o.			
p.	1,72	1,72	1,72	p.	0	0	0
q.	2,59	2,59	2,59	q.	2,59	0	0
r.	30,17	35,35		r.		44,83	41,38
s.	7,14	6,9	6,9	s.	6,9	1,67	4,31
t.	13,79	12,93	6,03	t.	6,03		
u.				u.			
v.	12,93	11,2	0	v.	0	0	
x.				x.	5,17		
22 In total	**76,94 á 10**	**93,89 á 12**	**68,09 á 10**	**22 In total**	**56,89 á 10**	**83,57 á 12**	**51,51 á 10**
	7,7	**7,8**	**6,8**		**5,7**	**6,9**	**5,1**
Percentage difference					**25,97 %**	**12,8 %**	**25 %**

- *"It is nice — less load because pulling up the syringes has stopped."*
- *"The workflow has become more flexible and quick."*
- *"It takes longer time during the mornings — up to 10–20 minutes."*

The work environment representative concluded:

"Using infusomat instead of injectomat, it was unambiguously clear that the interviewed anaesthesia nurses experienced a noteworthy reduction in physical strain, particularly regarding their fingers, hands, elbows, and shoulders."

Usage of utensils and sustainability

Using the injectomat was registered for 345 days and pr. day calculation showed, an average of 14,44 utensils , the cost amounted to 69,83 DKK and the CO_{2e} emissions totalled 1514,44 grams (Table 3).

Using the infusomat was registered for 339 days and pr. day calculation showed, an average of 8,43 utensils, the cost amounted to 60,33 DKK and the CO_{2e} emissions totalled 1008,37 grams (Table 3).

The results demonstrated that switching to infusomat led to a **41,6% reduction** in the number of utensils used per day, a 1**3,6% cost reduction**, and a **33,42% decrease** in daily CO_{2e} emissions (Table 3).

Discussion

The combined results from the DASH scores and the interviews indicate that the ergonomic flow on anaesthesia nurses' fingers, hands, elbows, and shoulders reduced when using infusomat instead of injectomat. Additionally, the utensil counts show a clear trend towards a reduction in utensil consumption, overall cost, and CO_2 emission.

However, not all anaesthesia nurses participated in the interviews, introducing a potential selection bias. It is uncertain whether those who did not attend were anaesthesia nurses without problems who found it unnecessary, or those with severe discomfort who were reluctant to come forward. This makes it difficult to determine if the interviewed participants are representative of the entire ergonomic workflow group. Furthermore, not all anaesthesia nurse completed the DASH questionnaire. This could be due to forgetfulness or perceptions that the questionnaire was unnecessary. The missing scores could introduce information bias in either direction: a low score might underestimate the difference between the two procedures, while a high score might exaggerate it. It is also possible that the manual registration of utensil use was not entirely accurate. The anaesthesia nurses were responsible for recording utensil use throughout their busy day, and some utensils may not have been consistently documented. However, this potential underreporting would likely affect both procedures equally, minimizing its impact on comparative results.

Despite these limitations, the data strongly suggest that using infusomat instead of injectomat in a Day Surgery setting improves ergonomic workflow for anaesthesia nurses.

Three challenges arose during the project, some of which we had not anticipated despite conducting a pilot study. These challenges included 1. A new workflow: Adjusting to the infusomat system required time and training. 2. Occlusion alarms: Alarms occurred more frequently with the infusomat setup than with the injectomat. 3. Hygiene concerns: Strict protocols had to be followed to maintain hygiene standards when reusing infusomat components.

A new workflow

Preparing the infusomat in the morning initially took 10–20 minutes longer compared to the injectomat. Those infusomats we had were more sensitive than the injectomat, making it essential to be precise when setting up the drop sets. To support the anaesthesia nurses, we developed pocket sized guidelines containing setup instructions and troubleshooting tips.

Despite the initial adjustment period, one anaesthesia nurses stated during the interviews after using the Infusomats for eight weeks: "This gives more time for observation and patient care." This suggests that, the time used in the morning preparation, are saved during the day, not having to prepare new syringes, between patients or during the surgery. Also, over time, as the setup becomes more familiar, morning preparation may become quicker and integrate naturally into the daily workflow.

Occlusion alarms

At the beginning of the project, we experienced unexpected occlusion alarms, particularly when administering bolus doses. This created an unsafe situation, and as an immediate safety measure, each anaesthesia nurse kept a syringe with 20 ml of propofol readily available. We initially inspected the infusomat preparation and setup for any errors but found no faults. Subsequently, we turned our attention to the patient side of the system.

We identified the problem; the double run TIVA-set and the drop set with two three-way taps required the medication to pass through a very narrow lumen distal to the double run TIVA-set. This likely contributed to the increased resistance and triggered the occlusion alarms.

To address the issue, we replaced the double run TIVA-set with two separate thin extension lines and a drop set equipped with three three-way taps. This modification maintained the flexibility of having additional medication access during anaesthesia while significantly reducing flow resistance — effectively resolving the occlusion alarm problem.

Hygiene

With the injectomat, the protocol was to remove the syringe between patients and clean the device (6). In contrast, with the Infusomats, the drop set remains in the Infusomat between patients, while the double run TIVA-set set is changed after each patient.

Using the infusomat the drop set to the infusomat is approved to be used up to 12 hours, in another hospital in Denmark, and the pharmaceutical company approves the use op to 24 hours (7, 14). In our Day Surgery Department, we use the same infusomat drop set during the dayshift, for 8 hours.

It is therefore important to note: if the infusomat drop set becomes contaminated and must be changed between all patients, the procedure would no longer be cost effective, environmentally friendly, or ergonomically advantageous. As listed in table 3, it is clear that the infusomat sets are the most expensive utensil pr. piece, therefore it is important to secure the cost effectiveness that one infusomat set is used as long as possible, max 12 hours (Table 3). (near here).

Also, looking at the CO_2 emission, the setup for the Infusomat almost has the same CO_2 emission as the setup for the injectomat, so have to replace a new infusomat drop set between each patient will make the procedure not environmentally friendly (Table 1).

It takes extra time setting up the infusomat drop set, and if cannot be used for a day extra time has to be in calculated, and thereby more twist and turns will be added, and the ergonomically advantageous will fade.

During the project, we only had access to a long infusomat drop set, which increased the risk of contamination if the lines touched the patient or the floor. To manage this, we rolled up the long line from the infusomat drop set and collected it in a small plastic bag, which was changed between every patient.

However, after the project, a pharmaceutical company produced a shorter infusomat drop set, eliminating the need for the small bag, simplifying the setup, and further improving workflow, hygiene and CO_{2e} emission (Table 1) (7, 8, 15-17).

A detailed hygiene instruction was developed and implemented to ensure that all staff followed correct procedures, maintaining patient safety throughout. However, a Swedish study from 2024 concluded that no risk of bacterial contamination was found when reusing syringes with two anti-reflux valves and changing only a 10 cm infusion line between patients (4). In our setup, we changed the entire double run TIVA-set , over 100 cm long, between each patient. Therefore, we believe that the risk of cross contamination between patients in our study setup is minimal.

Conclusion

Our study concludes that using infusomat instead of injectomat improved the ergonomic workflow for anaesthesia nurses, with up to a 25% reduction in physical strain on hands, fingers, elbows, and shoulders, after using infusomat for eight weeks.

In addition, we demonstrated substantial environmental and economic benefits with a reduction of 41,6% in the use of utensils, a 33,42% reduction in CO_{2e} emissions, and a 13,6% overall improvement in cost effectiveness.

Thus, infusomat represent a more sustainable, ergonomic, and cost efficient alternative to injectomat in a Day Surgery setting.

Perspective

This study was conducted in a Day Surgery setting characterized by many short operations throughout the day. However, the use of infusomat may also be beneficial in stationary surgery rooms where longer procedures are performed. We have no calculation towards that, but starting the day, making the infusomat setup, and only have one or two patients there will only have to be change utensils once having two patients. Using the injectomat the anaesthesia nurses has to draw up all syringes and use spikes and transfer needles as well, during the surgery and between patients (Table 2).

In such settings, starting the day with a complete setup, and only needing to change the medication bottles during the day, could further amplify the reduction in utensil use and CO_{2e} emissions, given the lower patient turnover.

The ergonomic benefits for the anaesthesia nurses could similarly be expected to continue or even improve.

However, additional studies are necessary to investigate whether the economic and ergonomic benefits observed in this study are consistent in settings with fewer, but longer, surgical procedures.

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