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**Exploring the consequences of using
i-Suite™ operating rooms:
A case study at Dagklinikken, Give Hospital**

May 2006

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1. Introduction

As part of a larger modernization process, two i-Suite™ operating rooms¹ were recently built and put into use at a orthopaedic day surgery clinic in Give Hospital. In the absence of previous documentation on the consequences of introducing these high technology operating rooms, it was decided to perform a case study to explore and document the experiences at Give Hospital. The case study approach is useful in the examination and understanding of complex situations and in the development of hypotheses for further studies (Yin 1989).

The study was undertaken by CAST - Centre for Applied Health Services Research and Technology Assessment, University of Southern Denmark, at the request of Stryker Europe, and in close collaboration with the management of the Department of Orthopaedic Surgery at Vejle and Give Hospital, and the nursing officer and chief surgeon at the day clinic at Give Hospital. The Planning Department at Vejle Hospital and the Department of Quality and Health Informatics at Vejle County provided data for the analysis of productivity.

The objective of the study was to generate hypotheses about the consequences for the clinic of implementing and using i-Suite™ operating rooms. Implementing and using the i-Suite™ operating room is a process consisting of three stages: planning stage, installation stage and training stage. This case study will only discuss the two first stages.

The case study comprised several steps, including review of the scientific literature and of relevant hospital documents, an observational study, interviews with the clinic staff and an explorative productivity analysis.

2. Study context

The establishment of two i-Suite™ operating rooms was just one of many changes that were recently undertaken at Give Hospital. This section provides a more detailed description of the context in which the

¹ i-Suite™ operating room where established in 1992 as the first integrated operating rooms and it become the genesis for the i-Suite™ launched in 2003.

operating rooms were introduced, and thus the context for the current analysis.

Give Hospital (situated in the city of Give) is a small hospital in the county of Vejle that offers medical and orthopaedic services. The orthopaedic services focus on mobility problems (e.g. knees, shoulder, hands and feet) and physical rehabilitation. One-day orthopaedic surgery is performed in a day clinic called Dagklinikken, which undertakes both orthopaedic surgical procedures and endoscopic examinations. Give Hospital has four operating rooms, of which two are i-Suite™ operating rooms and two are conventional operating rooms. The patient is admitted in the morning, operated on during the day, and discharged at the end of the day. In contrast, Vejle Hospital (situated in the city of Vejle) is the main hospital of Vejle County and has a broad range of highly specialized functions and acute treatment. The Department of Orthopaedic Surgery at Vejle Hospital performs both acute and highly specialized surgery. As an illustration of the different sizes of the Department of Orthopaedic Surgery at the two hospitals, in 2002 Vejle Hospital had approx. 23,500 visits to the casualty department, approx 8,800 outpatient treatments, approx. 2,900 hospitalizations (65% of those acute) and approx. 2,200 surgical procedures, while Give Hospital had approx. 600 visits to the casualty department, approx. 8,000 outpatient treatments and approx. 1,800 surgical procedures². About 20% of the patients treated at Give Hospital are patients living outside Vejle County.

Up until 2001, the situation was very different to the current one. The Departments of Orthopaedic Surgery at Vejle and Give hospitals had both offered a broad range of treatments and had no sub-specialties. Five surgeons worked in Vejle and three at Dagklinikken in Give; however, only one of the Give surgeons was based at Give Hospital, the other two being based at Vejle Hospital and taking turns to spend a few days a week at Dagklinikken. In addition, all the nursing and anaesthetic staffs were based at Vejle Hospital and worked at Give Hospital on rotation. These circumstances contributed to give Give Hospital, including Dagklinikken, a low status compared to Vejle Hospital. The main

² Source: www.vs.vejleamt.dk/ortopaedkir/Default.htm.

reasons cited for this low status were: the peripheral location and small size of Give Hospital, the lack of close affiliation for staff coming from Vejle, the run-down state of the buildings and equipment, the poor conditions in the operating rooms, the perceived low status of the surgery that was performed (e.g. varicose veins and ingrown toe-nails) and the small size of the recovery rooms (Departmental managers of the Orthopaedic Surgery Department at Vejle and Give Hospitals 2003).

In contrast to other Danish counties that were closing small-sized hospitals such as Give Hospital, the County of Vejle decided in 2001 to unite the hospitals in Vejle and Give into *one* hospital. The official name is now Vejle and Give Hospital; for the purposes of this report, however, the two locations are differentiated by referring to 'Give Hospital' for the location in Give, and 'Vejle Hospital' for the location in Vejle. The changes made in 2001 led to orthopaedic surgery being divided into five surgical sections (three in Vejle and two in Give). The two surgical sub-specialties at Dagklinikken (Give Hospital) are i) scopic surgery and sports injuries (non-acute surgery for shoulders, elbow, knee and ankle), and ii) hand and foot surgery (non-acute surgery for hand, wrist and foot) (Dagklinikken Give Hospital 2004).

In order to ensure similar conditions for staff at both hospital locations, it was decided that new and modern facilities would be provided at Give Hospital, including offices, examination rooms and operating rooms. Four operating rooms were established by keeping the two existing rooms and building two new i-Suite™ operating rooms. The first i-Suite™ operating room was established in November 2002 and the second in August 2003.

The i-Suite™ operating room is the main name of the family of surgical suites designed to create the optimal operating environment for the surgeon, the staff and the patient across surgical specialties (Stryker Europe 2005).

The i-Suite™ family have four members, that spans across all surgical specialities:

1. CVSuite™ designed to oblige great demands to communication and information for heart surgery,
2. OrthoSuite™ designed for minimally invasive, total joint and other orthopaedic procedures,
3. NavSuite™ designed for neurology, spine surgery, ENT (ear, nose and throat) surgery and orthopaedic surgery like knee and hips replacements.

4. EndoSuite® designed for a number of different kinds of surgery e.g. general surgery, gynaecology, ENT (ear, nose and throat) surgery, urology, and orthopaedic surgery (Stryker Europe 2005).

The i-Suite™ design is an overall solution starting from the needs and visions of the surgery department. Implementing the i-Suite™ operating rooms is a process containing of three stages: 1) the planning stage (technical requirements, schemes for practical arrangements, daily routine, procedures and time effectiveness), 2) installation stage (arrangement, kind of operations, working environment), and 3) training stage (technical training, basis knowledge, advanced knowledge and supervision).

The OrthoSuite™ and EndoSuite® are specially designed rooms for endoscopic surgery and examination (endoscopy). The operating equipment is high technology and includes direct control of equipment through voice-control (The Hermes Voice-Activated Control – since 2005 the name has changed to Sidne™) and touch-screen technologies. Flat panel monitors that hang from the ceiling can be moved to the desired position, and the operating table can be adjusted to suit the patient and the surgery. The equipment is easy to assemble and is controlled by a single console panel.

The i-Suite™ concept was developed by the American company, Stryker Corporation, which is a worldwide organization providing orthopaedic products and services (www.stryker.com). i-Suite™ operating rooms have been used since 1992 for cross-specialty minimally invasive and standard surgical surgery (Stryker MedSurg Group Europe 2003).

Working procedures were changed at Dagklinikken as part of the modernization process and the implementation of the i-Suite™ operating rooms. In contrast to the earlier system where the surgeons shifted between operating rooms, each operating room now has its own team of staff that is responsible for the planning and performing of each day's surgical procedures.

The alteration and modernization of Give Hospital had three overall aims. *Firstly*, the aim was to increase the weekly number of surgical procedures from 45 to 80 by increasing the number of outpatient department lines (from two to three), the number of operating lines (from two to three), the number of operating rooms (from three to four, of which two are i-Suite™ operating rooms and two are conventional operating rooms), and the number of staff (from 12 to 25 nurses and from 6 to 8 surgeons (Dagklinikken Give Hospital 2004).

The *second* aim was to facilitate the recruitment of new staff by offering modern facilities and good working conditions. The *third* aim was to improve patient records through the use of high technology and effective teamwork (Departmental managers of the Orthopaedic Surgery Department at Vejle and Give Hospitals 2003).

3. Study design

The project was undertaken as a case study that included i) a literature review, ii) a review of hospital documents, iii) an observational study, iv) interviews with staff of Dagklinikken at Give Hospital, and v) explorative productivity analysis. The case study approach was chosen because of the complexity of the subject and the indistinct boundary between the focus of the study (implementation and use of the i-Suite™ operating rooms) and the surrounding context. An investigation into the consequences that the i-Suite™ operating rooms have had for the hospital and its staff, needed to be conducted in the context of other concomitant changes according to the use of the operating room. This study is primarily focusing on the use of the operating room before and after the installation of the i-Suite™ operating room and secondarily on the changes in the physical and organizational environment at Dagklinikken as a part of the implementation of the i-Suite™ operating rooms. The training and education of the staff is not discussed in this study.

The following table provides an overview of the different methods and analyses used in this case study.

Table 1. Overview of methods and analyses in the case study

Method	Procedure	Analysis
Literature review	A search was made in the international scientific literature on the subject of dedicated minimally invasive surgery suites.	Identification of relevant articles for the case study, followed by a review of key findings.
Document review	Review of hospital documents that described the organization and goals of the day clinic. Meeting with clinic management.	Obtaining background information to increase researchers' awareness of the relevant issues. Identification of dominant topics for the staff interviews.
Observational study	Two researchers observed the work of the operating teams for one day.	Identification of dominant topics for the staff interviews.
Staff interviews	Semi-structured interviews with seven key informants.	Exploring the consequences of using i-Suite™ from the

		perspective of the staff.
Study of the case-mix	Information of the activity before and after the implementation of i-Suite™.	Macro-level analysis of the type and number of surgical procedures.
Study of productivity based on the number of procedures	Information of the activity before and after implementation of i-Suite™.	Macro-level analysis of productivity based on the patient-administrative system.
Study of productivity based on actual measurement of time use	Measurement of 'knife time' before and after implementation of i-Suite™.	Micro-level analysis of productivity based on actual measurement of time spent by the staff on specific tasks.

These different phases of the case study are described in more detail in the following sections.

4. Literature review

A systematic literature review was performed on the consequences of using i-Suite™ operating rooms or similar high technology operating rooms.

4.1 Methods

The information sources used were Medline (Silverplatter), Embase, Cochrane Library (including the HTA-database, DARE, NHSEED), and the Journal of Surgical Endoscopy. Further searches were instigated on the basis of the reference lists in the identified relevant literature. Articles were assessed for their relevance, validity and importance to the current study. The following search words were used to identify relevant articles:

EndoSuite OR surgery suite OR minimally invasive surgical suite OR MIS suite OR endoscopy operating room OR endoscopy OR endoscopic OR endoscopic operating room OR ergonomic operating room.

The literature search was made in 2004. Only articles in English were included.

4.2 Results

The literature review resulted in six relevant articles and one newsletter, as shown in Table 2.

Table 2. Overview of the literature included in the review

Author, technology and study design	Indication	Results
<p><u>Ohio State University 2002</u></p> <ul style="list-style-type: none"> - Laparoscopic surgery - Before-and-after study 	<p>Comparing data from two kinds of orthopaedic surgery (knee surgery and ligament reconstruction) before and after the installation of the computerized operating room.</p>	<p>Both operations were completed in less time after the installation, and the time between surgeries was also reduced.</p>
<p><u>Alarcon & Berguer 1996</u></p> <ul style="list-style-type: none"> - Laparoscopic surgery - Observational study 	<p>Comparing the furniture, equipment, cables and tubes that are present during open surgical procedures and laparoscopic surgical procedures.</p>	<p>Compared to open surgical procedures, laparoscopic surgical procedures were associated with increases in the percent of operating room space occupied, the median number of cables or tubes present, and the number of cables or tubes touching a member of the surgical team.</p>
<p><u>Albayrak et al. 2004</u></p> <ul style="list-style-type: none"> - Laparoscopic surgery - Random selection; observational study 	<p>The current state of ergonomics of Dutch operating rooms for laparoscopic surgery.</p>	<p>From an ergonomic point of view, current operating rooms are insufficient to perform laparoscopic surgery. Some of the reasons are i) the position and flexibility of the screens/monitors with respect to their weight and size, ii) the number of monitors and their interference with operating table or respirators, iii) the height of the operating table, and iv) the size of the operating room.</p>
<p><u>Herron et al. 2001</u></p> <ul style="list-style-type: none"> - Minimally invasive surgical suite - Descriptive study 	<p>Discussion of the theoretical and practical aspects of the design and description the implementation and utilization of the MIS-operating room in one specific hospital.</p>	<ol style="list-style-type: none"> 1) The design process requires a multidisciplinary approach that can take different needs into account. 2) The construction of the suite requires 6 months, during which time the room will be unavailable. 3) The room must allow flexibility in positioning the patient, be immediately available when required, and be perceived to provide numerous potential benefits to the operating team.
<p><u>Vereczkel et al. 2003</u></p> <ul style="list-style-type: none"> - Laparoscopic surgery 	<p>Discussion of the ergonomics and working</p>	<p>Some assessments have been made of the ergonomic</p>

Author, technology and study design	Indication	Results
- Descriptive study	environment of the operating room described in the literature.	aspects of laparoscopic surgery, and more are underway. There is still a lack of reliable and reproducible study data.
<u>Kenyon et al. 2001</u> - Minimally invasive surgery (MIS) suite - Time study	Comparing the amount of time required to set up and put away video equipment in the conventional operating room compared to a minimally invasive surgery suite.	MIS significantly reduces video set-up & put-away time; 226 and 202 seconds for conventional surgery and MIS, respectively.
<u>Luketich et al. 2002</u> - Minimally invasive surgical (MIS) suite - Time study; randomized trial	Comparing the nurse time spent on minimally invasive surgical procedures and standard operating room. N=30.	The operating time was 4.35 minutes shorter in MIS operations.

One of the articles referred directly to the Hermes voice-control system (Luketich et al. 2002). The newsletter (Ohio State University 2002) described a before-and-after study in which a computerized operating room similar to i-Suite™ was installed for two kinds of orthopaedic surgery (knee surgery and ligament reconstruction). Out of the six articles, three referred to laparoscopic surgery and three to (minimally invasive) surgical suites. Most of the articles were descriptions of the arrangement and use of the operating room (Alarcon & Berguer 1996; Albayrak et al. 2004; Herron et al. 2001; Vereczkel, Bubb, & Feussner 2003) and only two articles reported empirical studies such as time studies that involved comparison of a conventional operating room and a high-tech operating room (Kenyon et al. 2001; Luketich, Fernando, Buenaventura, Christie, Grondin, & Schauer 2002).

Much of the literature referred to the advantages and disadvantages of the working environment within a high technology operating room. The advantages reported included: a) more floor space due to fewer detachable cables and wires, b) ergonomic, functional and well-appointed working places that are purpose-built to suit the tasks of the surgeons and theatre nurses, and c) new electronic equipment e.g. voice-control systems (Herron, Gagner, Kenyon, & Swanstrom 2001). The study by Alarcon et al. (Alarcon & Berguer 1996) provided a description of the furniture, equipment, cables and tubes that are present during open and laparoscopic surgical procedures. It was concluded that there is

a significant trend towards greater operating room crowding during laparoscopic surgery because of the increasing number of cables and tubes used, and there is increasing likelihood that these cables touch and distract the surgical team. A Dutch study on the ergonomics of hospital operating rooms in the endoscopic era indicated that laparoscopic procedures are most often performed in conventional operating rooms that are unsuitable for endoscopic surgery (Albayrak, Kazemier, Meijer, & Bonjer 2004). The rooms are often too small for the large number of trolleys/consolas that are required, and monitors are typically placed on the consolas instead of being attached to booms in the ceiling. The i-Suite™ operating room has been suggested as a possible solution to such problems, as the equipment is assembled on one console, has ceiling-based monitors and uses state-of-the-art computerized techniques.

Two studies indicate a significant decline in knife time for surgical procedures in minimally invasive surgery suites (modern suites similar to i-Suite™ operating rooms), in comparison to knife time in conventional operating rooms (Luketich, Fernando, Buenaventura, Christie, Grondin, & Schauer 2002; Ohio State University 2002).

Apart from providing background information on others' experiences with high technology surgery, the literature review also aimed at identifying relevant topics that would be important to include in the study of the i-Suite™ operating rooms at Give Hospital. The following topics were identified: time savings during the surgical procedures ("knife time" of the surgeon and "nurse time" spent on adjusting the equipment), time savings between surgical procedures ("turn over time"), job satisfaction, working environment including placement of the equipment, ergonomics and the use of high technology equipment. These topics were considered relevant to the current study, despite the special focus on orthopaedics.

A randomized study of the use of Hermes voice-control system revealed fewer cases where the surgeon needed to ask the nurse to make adjustments or to assist with the camera, light, insufflator or phone calls (Luketich, Fernando, Buenaventura, Christie, Grondin, & Schauer 2002). With the use of Hermes voice-control, the surgeon him/herself can make adjustments to the camera, light and insufflator, thus freeing

the nurses for other tasks. A controlled study of the differences in set-up and put-away times between minimally invasive surgery suites and standard operating suites also revealed a reduction in “shifting time” (Kenyon, Urbach, Speer, Waterman-Hukari, Foraker, Hansen, & Swanstrom 2001).

5. Document review

A review of relevant hospital documents was performed in order to obtain more detailed information about the organization of Give Hospital and the activities undertaken at Dagklinikken.

5.1 Methods

Relevant documents describing the organization and goals of the day clinic were provided by the orthopaedic departmental manager at Vejle and Give Hospital, and the nursing officer and chief surgeon at Dagklinikken. The following documents were included in the review:

- A Profile of Dagklinikken – a report describing the clinic’s development and general approach, with a review of its organization (administrative set-up, day-to-day running of the clinic, patient capacity), staff (e.g. qualifications, responsibilities, staff policies) and type of patients treated (e.g. the types of surgical procedures offered, the physical conditions/facilities) (Nielsen, Kidmose, & Larsen 2003).
- Review of operative activity – a description of the operative activity undertaken in the clinic (e.g. professional criteria, productivity goals), the management structure, the clinic staff, work organization (e.g. teams, daily procedures), patient management and relationship to other departments (Dagklinikken Give Hospital 2004).
- Introduction to the orthopaedic surgery unit at Vejle and Give Hospital – a description of the administrative and professional organization of the orthopaedic surgery unit; intended as information for new staff and including policies, instructions and practical information (Departmental managers of the Orthopaedic Surgery Department at Vejle and Give Hospitals 2003).

- Slide show prepared by the orthopaedic surgery departmental manager about the changes undertaken at Dagklinikken (Nielsen 2004).

These documents were supplemented by meetings with the orthopaedic surgery departmental manager, and the nursing officer and chief surgeon at Dagklinikken.

5.2 Results

The documents and meetings provided detailed and comprehensive information about the organization and activities at Dagklinikken before, during and after the introduction of the i-Suite™ operating rooms.

Dagklinikken has four operating rooms, of which two are conventional and two are i-Suite™. Each operating room comprises one operating line. As noted earlier, Dagklinikken has two sub-specialties: i) scopic surgery and sports injuries, and ii) hand and foot surgery (Dagklinikken Give Hospital 2004). The i-Suite™ operating rooms are primarily used for the first mentioned sub-speciality.

The main staffs working in the operating rooms are theatre nurses and anaesthesia nurses, anaesthetists and surgeons. Dagklinikken has increased the number of nurses from 12 to 25 (15 theatre nurses and 10 anaesthesia nurses) and the number of surgeons from 6 to 8.

The orthopaedic surgical manager of Vejle and Give Hospital has overall responsibility for Dagklinikken, but the daily running of the clinic is managed by the nursing officer and chief surgeon at Dagklinikken. In addition, each of the two sub-specialties has a manager, who is responsible for the day-to-day planning of surgical procedures and staff. Each surgeon is responsible for his/her own operating line. The nursing management comprises the nursing officer and a nurse who is responsible for daily coordination. The anaesthesia staff is organized as a separate group, with management comprising a nurse officer and a consultant (Dagklinikken Give Hospital 2004).

The documents and meetings also identified a number of topics as being important to include as themes in the staff interviews. These topics are listed in section 6.2.

6. Observational study

The aims of the observational study were to gain an impression of everyday life at the clinic and to identify topics that would be important in exploring the organizational consequences of introducing i-Suite™ operating rooms.

6.1 Methods

The observational study was conducted by two researchers from CAST, who followed the work in and around an i-Suite™ operating room during the course of one day. Particular attention was paid to i) the number and type of staff present in the operating room, ii) the tasks undertaken, iii) the communication and cooperation between staff, and iv) the time used in connection with the various tasks. The observations were recorded in a logbook so as to give a flash indication of everyday life at the clinic that would contribute to the knowledge base for producing an interview guide.

6.2 Results

The following topics were identified from the observational study and the document review/meetings as being important themes to include in the later interviews with staff:

- Structural aspects: need for improvements in the physical setting as well as changes in the type of surgery offered; the ambition for Give Hospital to become “the pearl of Mid-Jutland”; section management/sub-specialization; the uniting of the hospitals in Vejle and Give into one hospital.
- Management and cooperation: methods to increase productivity and quality; production efficiency; decentralization of responsibility; specialization/advanced surgery; the teamwork approach.

- The working environment: the environment the new facilities provided (including the high technology operating rooms/equipment, recovery rooms, offices); the social environment; ergonomics.
- Personnel factors: staff recruitment; permanence of employment at Give Hospital; advantages of working at Give Hospital (day duty only with no weekend work, location); staff interactions and cooperation; cultural and attitudinal changes.

These topics formed the basis for composition of the initial interview guide to be used in the next phase of the project.

7. Interviews: methodology

This chapter describes the methods used for conducting the interviews and analyzing the resulting data. The results themselves are presented in the following chapter.

7.1 Interview procedure

Interviews were conducted with seven staff members at Dagklinikken. These 'key informants' were identified through the use of the "cob web method" based on the following criteria:

- Currently working in the i-Suite™ operating room.
- Had worked at Dagklinikken both before (or during) and after the organizational changes, including introduction of the i-Suite™ operating rooms.
- Represent the various staff groups working at Dagklinikken (including nurses, surgeons and anaesthetic staff).
- Considered to be representative of their respective professional group in their attitudes towards the organizational changes and the introduction of the i-Suite™ operating rooms.

The seven key informants were two theatre nurses, one assistant nurse, two surgeons, one anaesthetist and one anaesthesia nurse. Semi-structured interviews were conducted in June and September 2004 using an interview guide that was designed in the light of the results from the document review/meetings and the observational study. This interview

guide was updated as new information or topics emerged from the interviews. Each interview took about 1-1½ hours.

The interviews comprised the following steps (Kvale 1994):

- The key informant described his/her attitude to various topics.
- The key informant described issues and consequences related to their experiences.
- The interviewer condensed and interpreted the opinions provided and “returned them to sender”.

The objective of the interviews was to explore the consequences of the use of i-Suite™ operating rooms for work productivity, work processes, and interactions/communication amongst the staff. The consequences of the other changes (other than the i-Suite™ operating rooms) that were made at Dagklinikken were discussed if they were considered to be relevant to the acquisition and/or implementation of the i-Suite™ operating rooms.

7.2 Analytical approach

A descriptive approach was taken in order to examine and summarize the key topics that were identified as being important factors and/or potential problem areas in the introduction and running of i-Suite™ operating rooms for orthopaedic surgery.

The analysis consisted of two main steps (Hansen et al. 2001;Kvale 1994):

- Identification of the dominant topics in each interview; including analysis of how these topics interconnected with each other, both from a general perspective and in the case of specific problem-oriented situations.
- More specific identification of factors directly related to the introduction of i-Suite™ operating rooms.

This last step formed the basis for a third step:

- Generation of hypotheses.

Identification of dominant topics: The information emerging from each interview was structured according to the topics that were mentioned or discussed by the key informant. The discussion of a particular topic could either be broad and non-specific, or related to a particular situation or event; the data itself consisted of opinions or short statements of fact. An examination was made of how each topic was linked in the same sentence or discussion with other topics; comparisons were also made between informants with respect to the topics mentioned and any differences of opinion or fact. New topics that emerged during the course of the interviews were included in subsequent interviews (Borum & Enderud 1980).

Identification of factors related to the implementation and use of the i-Suite™ operating rooms: As the study's objective was to assess the consequences of the implementation and using of i-Suite™ operating rooms the interviews were focusing on the reactions and attitudes of the staffs to the changes made at Dagklinikken before and after the implementation and installation of the rooms. This formed the basis for the generation of hypotheses of relevance for the further measurement of the effects of introducing and using i-Suite™ operating rooms in orthopaedic surgery.

Generation of hypotheses: Several hypotheses were generated on the basis of the interviews at Dagklinikken. The hypotheses should be seen as possible outcomes of the introduction of i-Suite™ operating rooms and the resulting organizational changes. Operationalizing these hypotheses into measurable objectives could be done in further research studies e.g. qualitative studies about work organization and cooperation, supplemented by quantitative time use studies and job satisfaction surveys.

8. Interviews: results

Seven key informants among the staff of Dagklinikken discussed the introduction and use of i-Suite™ operating rooms in the clinic. The information that emerged from these interviews was used to identify main topics related to the working conditions at Dagklinikken. These topics could be divided into three main groups:

- 1) *Technology*. Technical effects caused by the introduction and use of i-Suite™ operating rooms in the clinic.
- 2) *Physical environment*. Effects caused by the changes in physical working environment inside and outside the i-Suite™ operating rooms.
- 3) *Organizational environment*. Effects caused by the changes in the organisational environment at Dagklinikken.

8.1 Technology

The key informants mentioned several consequences of the use of i-Suite™ operating rooms at Dagklinikken caused by the opportunities of the new technology.

In the i-Suite™ operating room, the surgeon can control the surgical equipment through voice commands. The surgeon can, for example, brighten or reduce the surgical lighting, increase or decrease the water pressure of the irrigator, take photographs, or switch the drill on and off, merely by saying the request aloud. Previously, the surgeon had to ask the theatre nurse to push the appropriate buttons for these tasks and then wait for the equipment to be adjusted. The voice control facility thus allows both the surgeon and the theatre nurse to focus more closely on the operative site itself. The surgeon is distracted for a shorter time by equipment settings and can better focus on the patient, while the theatre nurse has fewer tasks and feels less pressured during the operation. The informants reported that the consequences of these changes were better cooperation between theatre nurse and surgeon during the surgical procedures, and a less stressful environment.

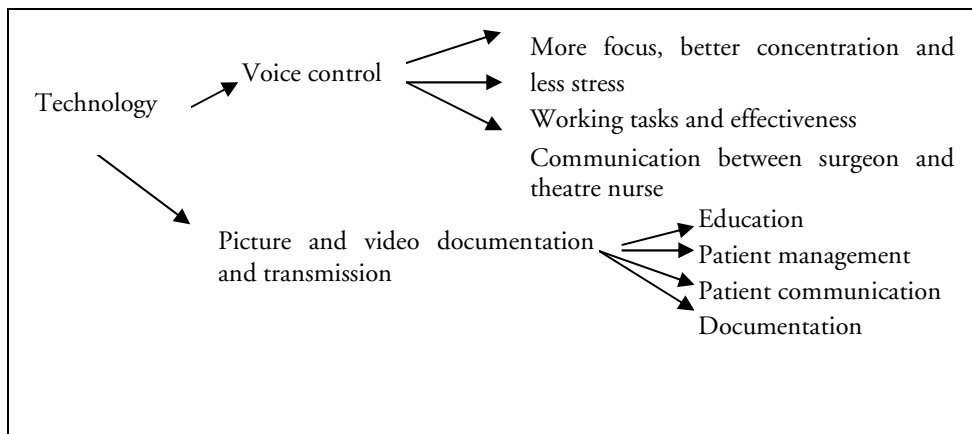
Hypothesis 1	The use by the surgeon of voice control to activate the equipment results in changes in the division of labour and an altered cooperation between surgeon and theatre nurse. As a consequence, both surgeon and theatre nurse can better focus on their own tasks and experience less stress during the operation.
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The improved technical possibilities in the i-Suite™ operating room for taking pictures and making video recordings allow the operative techniques to be shown for evaluative and training purposes. The

operation can be directly transmitted to others either inside or outside the operating room, although the latter option has not yet been used at Dagklinikken. The voice control facility allows the surgeon to take pictures more easily, and the quality of the pictures is also better, being sharper than before and allowing details to be seen more easily. It was reported that the surgeons make much more use of pictures than before and use this facility in nearly every operation – both for documentation purposes and as part of the patient record. Most patients receive a printed picture in which they can see the procedure that has been undertaken. It was the impression of the clinic staff that the patients are very pleased with this illustrative record of their operation, which they can take home with them. The pictures can also be printed or downloaded to a compact disk and sent to colleagues to facilitate discussion of the operation outcome and of follow-up treatment, e.g. at the radiology department at Vejle Hospital. This is of diagnostic benefit for the surgeon and may also have consequences for patient treatment.

Hypothesis 2 The improved technical capabilities for taking pictures and video recordings during operation provides better documentation of the operative procedure, a wider information basis for communication with patients and colleagues, and alternative methods for the training of surgical and nursing staff.

Figure 1. Technical effects of the implementation of i-Suite™ operating room



8.2 Physical environment

The physical environment is divided into the effects inside and outside the i-Suite™ operating rooms. The first part is mostly associated with the planning and installation stage in the implementation of the i-Suite™ operating rooms where Stryker in cooperation with the staff at Dagklinikken described how to arrange and act in the i-Suite™ operating rooms to make the most effective use.

8.2.1 Physical effects inside the i-Suite™ operating rooms

The physical set-up of the i-Suite™ operating room has a large influence on the amount of working space that is available for the surgical team. Much of the equipment is suspended from the ceiling and there are only a few consoles on the floor; this means that the floor is largely free of cables and tubes. There is less risk of falling over a cable or accidentally pulling out a plug, and there is more free space around the operating table.

Both the surgeons and the theatre nurses reported that they had become more aware of the working environment in the operating room. For each type of surgical procedure, they have produced a scheme that indicates the appropriate location for the equipment, instruments and console, and the setting for the operating table. It had been hard at the start for some of the theatre nurses to learn how to navigate the equipment that hung from booms on the ceiling and to ensure sufficient room for the swing arm of the equipment. It was necessary in one of the operating rooms to remove a locker to provide more space for the surgical equipment.

Some problems were reported in relation to the size of the operating room. The i-Suite™ operating room is narrow, and the low ceiling means that staff can easily hit their heads on the equipment hanging down. The sizes of the two i-Suite™ operating rooms are: Suite 1: 5.75m (length) x 5m (width) x 2.83m (height). Suite 2: 6m (length) x 5m (width) x 2.73m (height). Stryker recommend a suite size of: 6m (length) x 6m (width) x 3m (height). That means that the ceilings in the two i-Suite™ operating rooms at Dagklinikken are too low and the rooms are too narrow compared to recommended standards whereas the length in one

of the rooms is too short. The anaesthetic staff considered the operating room to be too narrow; when the anaesthesia nurses go in and out of the operating room during the operation they risk disturbing the surgeon and theatre nurse. It was recommended that future implementation of i-Suite™ operating rooms should carefully consider the positioning of the anaesthesia nurse in the operating room.

The theatre nurses reported that the placing of depot articles in lockers inside the operating room had made these articles more accessible – earlier they had to go out of the operating room to get them, which had created an undesirable flow of movement in and out of the operating room during the operation.

Both the surgeons and the theatre nurses were satisfied with the new flat screens that are suspended from the ceiling. The staffs considered that they now pay more attention to their working positions. The screens are easier to place in the correct position in front of the surgeon and the theatre nurse, which helps to avoid a poor working position. The theatre nurses now have their own screen so that they can follow the work of the surgeon without turning their heads to look at the screen. Both the surgeons and the theatre nurses were of the opinion that the improved equipment and more practical working set-up had resulted in fewer headaches and less back pain, and a better overall working environment, including greater job satisfaction.

Hypothesis 3	The size of the operating room and the physical arrangement of the equipment and instruments are important for the ergonomics of the working environment and the overall working environment.
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Hypothesis 4	Making schemes for appropriate locations and setting for each type of operation in the i-Suite™ operating room cause better arrangements and working environment inside the operating room.
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8.2.2 Physical effects outside the i-Suite™ operating rooms

The surrounding physical environment was also altered through refurbishment of the recovery room, staff offices and other operating rooms at Dagklinikken. The staff considered that these changes were positive for Give Hospital and Dagklinikken, in that they reflected a willingness to invest in the hospital. They felt that the modernization of

Give Hospital, including the implementation of i-Suite™ operating rooms, has been important for operative productivity, for the survival and image of Dagklinikken and Give Hospital, and for recruitment of staff to Dagklinikken.

Productivity and efficiency

One of the objectives in refurbishing the operating rooms was to increase productivity. The county politicians and the managers of Vejle and Give Hospital have set a new goal for Dagklinikken to perform an average of 80 surgical procedures per week – corresponding to an increase in production of about 80%. The clinic staffs are aware of this goal and can recognize the new focus on productivity that was not previously a major factor in their work. The doctors find this change of focus useful in making the work at Dagklinikken more efficient e.g. through improved communication, greater cooperation between the professional groups, and better work planning. Some of the nurses see the focus on productivity as a pressure and a potential source of stress.

The refurbishment of the operating space included the building of additional operating rooms, the closure of the sterilizing room and the transfer of instrument sterilization to Vejle Hospital. This means that the nurses no longer rinse, sterilize and pack the instruments for the next day's surgical procedures at the end of day, and the time saved is now used for surgical procedures.

Survival and image of Give Hospital and Dagklinikken

The staff felt that the modernization of Give Hospital has made Dagklinikken a respected part of Vejle and Give Hospital and has improved its image both inside and outside the county. Many patients from other counties are treated at Dagklinikken, thus creating a useful source of income for Vejle and Give Hospital. The city also benefits through the provision of jobs and the good image gained from having a highly reputed hospital.

The i-Suite™ operating rooms have had much attention from the media and from health professionals throughout Denmark. This has led to external expectations that the staffs at Dagklinikken are also more expert than before because of the new technology. Apart from the nurses need

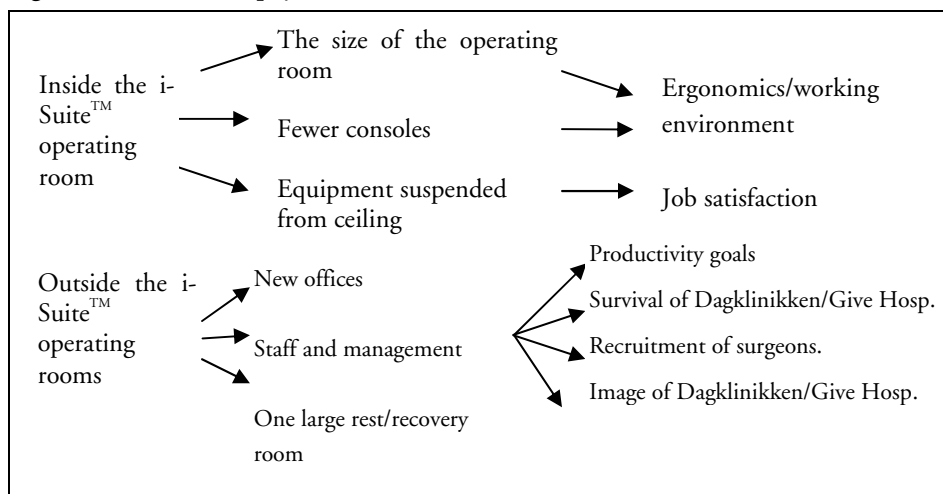
to maintain and update surgical procedures specifications some of the theatre nurses consider that they also need to devote time to their own professional development, e.g. by evaluating their work in the form of journal articles. Professional development was considered to be important to the theatre nurses as a group to make the most out of the changes.

Staff recruitment

The introduction of i-Suite™ operating rooms has been crucial in the recruitment of surgeons to Dagklinikken. It is likely that many of them would not have accepted the jobs without the availability of new technology and possibilities for new surgical approaches. The surgeons had previously been permanently employed at Vejle Hospital and had taken turns to commute to Dagklinikken. Today, all surgeons are employed on a permanent basis at Give Hospital. This has produced a more positive engagement in the daily activities, with improved communication both amongst the surgeons themselves and with the theatre nurses and anaesthesia staff.

Hypothesis 5 The modernization of Dagklinikken, including the construction of two high technology operating rooms (i-Suite™), has been crucial for the survival of a small hospital and for the image of the clinic among health professionals, local politicians, hospital managers and staff.

Figure 2. Effects in the physical environment



8.3 Organizational environment

Associated to the implementation of i-Suite™ operating rooms, there have been several organizational changes at Dagklinikken. These changes could have been made without a concomitant modernization of the operating rooms, but they are important to the daily routines undertaken in the operating rooms and the basis for making the most out of the i-Suite™ operating rooms.

In the planning and installation stages of the implementation of i-Suite™ operating rooms a range of organizational changes were introduced with the goal of helping the staff to work more effectively. Three main changes were: i) alteration of the conditions of employment to provide permanent positions based at Dagklinikken, ii) establishment of a team for each of the operating rooms, and iii) sub-specialization in the types of surgical procedures undertaken at Dagklinikken.

Permanent employment

Previously only the theatre nurses were employed on a permanent basis at Give Hospital. The anaesthesia staff and the surgeons were employed at Vejle Hospital and worked at Dagklinikken for only a few days each month. Today all the staffs, except the anaesthetists, are employed on a permanent basis at Dagklinikken. The anaesthetists are still employed at Vejle Hospital and come to Give Hospital 2-3 times a week; the work is shared, however, between the same four doctors. Many new staffs have been recruited to Dagklinikken, partly due to the need to double the number of theatre nurses and also due to the unwillingness of some employees who had previously commuted from Vejle Hospital to work full-time at Dagklinikken. Only two of the anaesthesia nurses and a few of the current surgeons now working at Dagklinikken were previously employed at Vejle Hospital.

The provision of permanent staff employment at Dagklinikken means that staff members are more involved in the daily work activities due to a greater feeling of affiliation and a closer relationship with their colleagues. There has been improved cooperation both within and between the different professional groups. The anaesthesia nurses had been doubtful about the benefits of changing to permanent positions at Dagklinikken, but they now considered their group to be more unified

than before, as they are a small group of permanent staff who can more easily meet on a daily basis to discuss clinic activities and patient follow-up. The change had thus given them both stability and continuity in their work.

The surgeons reported that the permanent employment of both surgeons and anaesthesia nurses had provided greater stability with each professional group, better cooperation between the groups, and more staff involvement in daily planning.

The theatre nurses felt that the permanent employment of surgeons and anaesthesia nurses had been of great importance. They reported that it had resulted in better attitudes and greater involvement in the work, and everybody felt important and responsible. There were indications that the process of change had not been easy, however, as people had had to learn how to cooperate with each other in a different way than before.

A disadvantage of permanent employment at Dagklinikken is that the staffs feel detached from the rest of the orthopaedic surgery department, which is located at Vejle Hospital; Dagklinikken effectively works as a separate department. The previous commuting of staff from Vejle had given a greater feeling of belonging to the rest of the department. Problems have also arisen from the doubling of the number of theatre nurses, with the employment of many newcomers, and the transfer of instrument sterilization to Vejle Hospital. Before these changes, the theatre nurses ended their day with tasks such as rinsing, sterilizing and packing the instruments, which gave them an opportunity to talk together about work or private matters, and brought them closer together. The transfer of instrument sterilization was also reported to be a disadvantage for the newcomers as they are less exposed to the different instruments e.g. in learning their names, which instruments to be used for which surgical procedures and how they should be packed. The group of theatre nurses has also been divided somewhat by the creation of operating room teams and the introduction of sub-specialization. This means that the theatre nurses no longer have so many tasks in common, but instead have their own specialized tasks and affiliations.

Hypothesis 6	Employment of staff on a permanent basis improves stability and continuity within the organization, and fosters greater involvement and affiliation among the staff. This could lead to more efficient use of the i-Suite™ operating room.
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Operating teams

The establishment of operating teams means that staffs are attached to a particular operating room for a whole day, and function as a team. Each team consists of a surgeon, an anaesthesia nurse, an anaesthetist, two theatre nurses (one “scrub nurse” who is sterile and assists the surgeon, and one “circulating nurse” who is not sterile), and a hospital porter. The team is responsible for planning and carrying out the surgical procedures of the day. The staffs considered that the creation of teams has led them to become more effective in their work, as they have become more familiar with each other’s work practice and need to concentrate on only one operating room with one or two different types of surgical procedures each day. The main challenges for the teams are effective communication, effective planning of the operations, and ensuring that the needs of the whole team are taken into consideration. The surgeons were of the opinion that the establishment of teams has improved the planning and working processes, thereby ensuring optimal use of the i-Suite™ operating rooms. The theatre nurses felt that further work is required to improve team functioning, particularly due to the different prevailing attitudes towards working in teams. They would like greater involvement of the team in the planning of the day’s work to avoid, for example, an insufficient number of rest breaks during the course of the day. The staffs have also had to learn how to appropriately inform and involve the other members of the team, and there is now a closer relationship between the staffs in the operating room. The hospital porter has also been drawn into the team to ensure that he/she comes to the room at the appropriate time with the appropriate equipment. One of the porters has specialized knowledge about the operating table in the i-Suite™ operating room and can adjust this quickly and in accordance with the requirements for each different type of surgical procedure.

The establishment of teams has led to better planning, communication and cooperation between the staff members. This was not always easy at the start, however, for example in determining how tasks and

responsibilities should be divided between the surgeons and the anaesthetists, and especially due to the desire to produce a set of guidelines and rules of cooperation.

It was considered that the change to teamwork has resulted in time savings. The theatre nurses felt that this was due to the more precise guidelines for the location of equipment in the operating room, while the surgeons felt that the team worked more effectively and used less time to prepare for surgical procedures.

Hypothesis 7	Organization of the staff in each operating room into a team results in better cooperation between the different professional groups, a clearer division of responsibility, and more effective work practices. This could lead to a more efficient use of the i-Suite™ operating room.
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Sub-specialization

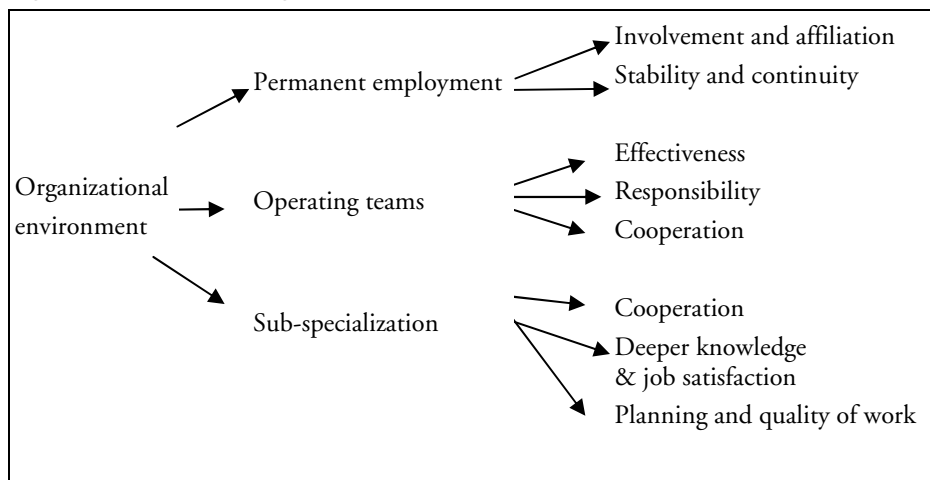
As part of the changes made in 2001, the Department of Orthopaedic Surgery at Vejle and Give Hospital was divided into five surgical sections, of which two are based at Dagklinikken. These two sub-specializations are i) scopic surgery and sports injuries of the shoulder, elbow, knee and ankle, and ii) hand and foot surgery. The operations can be categorized as: i) arthroscopies of shoulder/elbow/knee/ankle/wrist, ii) open shoulder surgery, iii) varicose veins, iv) hand surgery, v) foot surgery, vi) lipoma removal, vii) treatment of ingrowing toenails, iix) removal of osteosynthetic material (e.g. sutures, pins, plates, etc.) and ix) wrapper reduction (Nielsen, Kidmose, & Larsen 2003). The surgery (including arthroscopy) of shoulder and knee is performed primarily in the two i-Suite™ operating rooms, while the other surgical procedures are performed primarily in the two conventional operating rooms. All staffs are now sub-specialized in one way or another. Although this has been a new undertaking for the nurses at Dagklinikken, it follows the general tendency towards sub-specialization in nursing. The surgeons thought that the nurses had become more knowledgeable of particular subjects and more interested in their work. This had resulted in better cooperation between the surgeons and nurses, and had changed the perception that nurses were there to serve the surgeon. The theatre nurses reported greater job satisfaction through knowing more about a particular subject area, but were wary of becoming so specialized that the work became too limited and narrow.

The anaesthetic staff was also positive about sub-specialization. They found it easier to plan their work, which had become better defined, especially in the i-Suite™ operating rooms. One of the surgeons considered that sub-specialization makes better surgeons as it allows them to concentrate on those surgical procedures that they are best at performing.

The staff considered that it was important for the efficient use of the i-Suite™ operating rooms to have operating teams or a similar kind of management – especially since efficient use of the i-Suite™, including the voice-control facility, requires more distinct job descriptions for each staff group.

Hypothesis 8 Specialization of staff according to the type of surgical procedure allows more efficient planning and improves work quality due to deeper knowledge and better cooperation within and between the different professional groups.

Figure 3. Effects in the organizational environment



9. Explorative productivity analysis

The productivity analysis at Dagklinikken, Give Hospital was undertaken using two different approaches: firstly, the measure of productivity was a detailed measurement of the actual time used (‘micro-level’); secondly, the measure of productivity was the production/output in terms of surgical procedures (‘macro-level’). In both approaches the

analysis took the form of a *before-and-after study*, where the different productivity measures (time use and the number of procedures) were measured at specified time periods before and after the implementation of the i-Suite™ operating rooms.

The macro-level analysis of productivity centred on the activities at Dagklinikken before and after the establishment of the i-Suite™ operating rooms in November 2002 and August 2003. The year 2001 was selected as the comparative year *before* implementation of the i-Suite™ operating rooms, as productivity was not yet influenced by an incentive-creating fund initiated by the Ministry of the Interior and Health (the so-called '*Løkke-posen*', which aimed at rewarding increases in activity at Danish hospitals). The year 2004 was the most recent year *after* implementation of the i-Suite™ operating rooms. The activities at Dagklinikken only cover surgical procedures, that is to say the consultations in the outpatient department.

The two kinds of productivity measurement were based on different data systems. The use of time was based on registrations in the Electronic Patient Record (EPR) system, which contains data directly registered by the staff before, during and after the operation. The number of procedures was obtained from the patient-administrative system called 'Det Grønne System' (GS), which was managed by Vejle County. Both the EPR System and the GS contain data on different types of hospital procedures. The GS categorizes the procedures into three types: i) primary, ii) most important and iii) part procedures. In the following analysis, the procedures are divided into two groups: *primary/most important procedures* and *part procedures*. Definitions of the procedures are provided in section 9.1.1.

The original intention was to measure the number of procedures and the productivity by using the Diagnosis Related Group system (DRG-system) for inpatients and the DAGS-systemet (Danish Outpatient Group System) for outpatients. The DRG-system and the DAGS-system are both based on a network database called eSundhed at the National Board of Health and represent the price of the procedures, based on the value of the Diagnosis Related Group (DRG-value) and Danish Outpatient Group (DAGS-value). The database contains data from

primary/most important procedures only, which means that part procedures are not included. As these part procedures form a major part of the activity at Dagklinikken – e.g. arthroscopic procedures in knee and shoulder is mostly linked to other procedures - it would not be useful to base the calculation of productivity on the number of primary/most important procedures only.

Case-mix is an important parameter for the productivity analysis. The case-mix at Dagklinikken, which changed during the course of the study, is described in section 9.1. Results of the productivity analysis are presented in sections 9.2 (micro-level) and 9.3 (macro-level).

9.1 Case-mix

Case-mix refers to the types and numbers of surgical procedures performed. Each surgical procedure has a multi-level code that makes it possible to categorize the procedures into sub-specializations.

9.1.1 Case-mix: methodology and costs

Data on the type and number of surgical procedures were extracted from the GS at Vejle County, and covers all inpatient and outpatient surgical procedures at Dagklinikken in the period from January 2001 to June 2005. *Primary/most important procedures* were those procedures most directly related to the patient's diagnosis, or those that demanded the most resources in cases where the patient had more than one treatment or diagnosis (Borum 2000). *Part procedures* were those that were not considered to be the primary/most important procedure (Borum 2000). Table 3 summarizes the information obtained, and includes both part and primary/most important procedures. The primary/most important procedures form a part of 57%-67% of the surgical procedures while the rest of the procedures are part procedures.

Table 3. All surgical procedures (primary/most important procedures and part procedures) from January 2001 to June 2005 for inpatients and outpatients at Dagklinikken, Give Hospital

Surgical procedures	2001	2002	2003	2004	2005 ^{*)}
Musculoskeletal system	1,829	1,932	3,597	4,759	2,145
Nervous system	302	403	269	422	149
Eye and its surroundings	2	0	1	0	0
Peripheral vascular & lymphatic systems	759	307	135	129	30
Skin and subcutaneous tissue	203	192	157	251	103
Total	3,095	2,834	4,159	5,561	2,427

Note: *) Only half a year is included, from January to June 2005.

Source: "Det Grønne System" (GS), Vejle County

As shown in Table 3, most of the surgical procedures were related to the musculoskeletal and nervous systems. Looking at the number of surgical procedures over time, there was a decline in the number of surgical procedures related to the peripheral vascular and lymphatic systems, and an increase in the number of musculoskeletal surgical procedures. While in 2001 and 2002 musculoskeletal system procedures comprised respectively 59% and 68% of the total surgical procedures at Dagklinikken, it had increased to 86% in 2003 and 2004.

The data in Table 3 covers both inpatient and outpatient surgery, but operations in inpatient surgery form only a small part of the total number of surgical procedures. In 2001 there were 132 inpatients from Vejle Hospital operated at Dagklinikken; 108 patients in 2002, none in 2003, 1 in 2004 and 145 patients in 2005. Most of these inpatients had surgery for problems involving the nervous system.

9.1.2 Case-mix in musculoskeletal surgery

The surgical procedures at Dagklinikken are mainly for musculoskeletal problems involving the elbow, ankle, foot, wrist, hand, knee and shoulder. The two i-Suite™ operating rooms were established in November 2002 and August 2003; the number of operating rooms was thus increased from three conventional operating rooms to two i-Suite™ and two conventional operating rooms. In 2003 Dagklinikken started using one of the i-Suite™ operating rooms for shoulder/upper arm surgery, and the frequency of knee/lower leg surgery was increased. These changes are reflected in Table 4, which shows the case-mix for

musculoskeletal surgery during the period 2001 to 2004. From 2003 to 2004 there was an 81% increase in shoulder/upper arm surgery. A comparison of the number of surgical procedure in knee/lower leg surgery before and after implementing the i-Suite™ operating room (2001 vs 2004) shows that the number of procedures has more than doubled.

Table 4. All musculoskeletal surgical procedures (primary/most important procedures and part procedures) from January 2001 to June 2005 for inpatients and outpatients at Dagklinikken, Give Hospital

Year	2001		2002		2003		2004		2005 ¹⁾	
	Count	%	Count	%	Count	%	Count	%	Count	%
Surgical procedures										
Elbow/forearm	52	2.9	26	1.3	29	0.8	28	0.6	6	0.3
Ankle/foot	195	10.7	257	13.3	445	12.4	672	14.1	315	14.7
Pelvis	1	0.1	0	0.0	0	0.0	1	0.0	0	0.0
Hip/thigh	9	0.5	9	0.5	3	0.1	1	0.0	3	0.1
Wrist/hand	292	16.0	439	22.7	418	11.6	577	12.1	1	0.0
Knee/lower leg	1,268	69.3	1,195	61.9	2,244	62.4	2,653	55.8	1,268	59.1
Back/neck	3	0.2	4	0.2	4	0.1	2	0.1	10	0.5
Shoulder/upper arm	9	0.5	2	0.1	454	12.6	825	17.3	542	25.3
Total	1,829	100	1,932	100	3,597	100	4,759	100	2,145	100

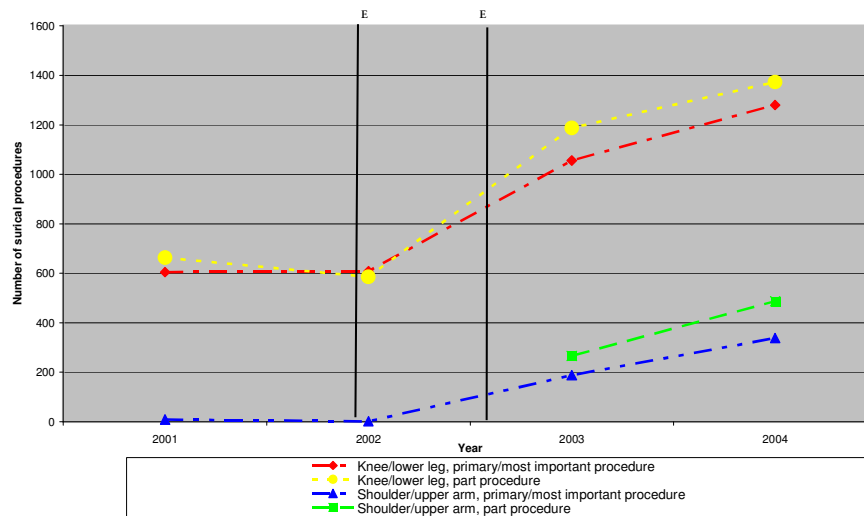
Note: ¹⁾ Only half a year is included, from January to June 2005.

Source: "Det Grønne System" (GS), Vejle County

While in 2001 knee/lower leg surgery comprised 69% of the total surgical procedures at Dagklinikken, it had declined to 56% in 2004; over the same period shoulder/upper arm surgery increased from under 1% of the total surgical procedures in 2001 to 17% in 2004. The percentage of elbow/forearm surgery declined from 2001 to 2004 and comprises only a small part of the total case-mix in 2004. Since 2001 there has also been an increase in the number of ankle/foot and wrist/hand surgical procedures.

Figure 4 shows the distribution of shoulder/upper arm and knee/lower leg surgery, categorized as either primary/most important surgical procedure or part procedure, both in- and outpatient surgery are included.

Figure 4. The number of shoulder/upper arm and knee/lower leg surgical procedures as primary/most important procedures and part procedures, for inpatients and outpatients at Dagklinikken, Give Hospital



Source: "Det Grønne System" (GS), Vejle County

Note: The two vertical lines named 'E' indicate the establishment of the i-Suite™ operating rooms in November 2002 and August 2003.

The i-Suite™ operating rooms are mostly used for arthroscopic surgical procedures, predominantly related to shoulder/upper arm and knee/lower leg surgery. The micro- and macro-level productivity analysis of the i-Suite™ operating rooms will focus, therefore, on these surgical procedures, which in the next two sections are referred to as 'arthroscopic knee surgery' and 'arthroscopic shoulder surgery'.

9.2 Productivity at the macro-level

The macro-level analysis of productivity centred on the activities at Dagklinikken before and after the establishment of the i-Suite™ operating rooms.

9.2.1 Methods

Surgical activity data were obtained from the GS at Vejle County, and covered procedures performed at Dagklinikken during January 2001 to June 2005 for both patients from the orthopaedic department at Vejle Hospital (code 01.9) and patients at Dagklinikken (code 01.6). The diagnostic codes for the arthroscopic procedures evaluated were KNBA11 (shoulder/upper arm) and KNGA11 (knee/lower leg).

Arthroscopic surgical procedures are mostly made as a part of another surgical procedure.

9.2.2 Results

From 2001 to 2005 5,183 arthroscopic surgical procedures were performed (Table 5). Most of these (70-95% throughout the period) were part procedures, i.e. they were neither the primary nor the most important procedure for the patient.

Table 5. Arthroscopy surgical procedures (part and primary/most important procedures) for outpatients in 2001 to 2005 at Dagklinikken

Arthroscopic surgical procedures	Shoulder/upper arm (KNBA11)		Knee/lower leg (KNGA11)		Total
	Primary/most important	Part	Primary/most important	Part	
Year					
2001	0	0	146	417	563
2002	0	0	148	353	501
2003	4	179	140	856	1,179
2004	8	315	201	903	1,427
2005	17	367	176	953	1,513
Total	12	494	635	2,529	5,183

Source: "Det Grønne System" (GS), Vejle County

As all of the arthroscopic shoulder surgery was performed in 2003 and 2004, this type of surgery could not be assessed in the before-and-after evaluation. The number of arthroscopic surgical procedures for shoulder/upper arm problems increased by 77% from 2003 to 2004.

A comparison of the amount of arthroscopic knee surgery before and after the implementation of the i-Suite™ operating rooms revealed an increase of 541 procedures between 2001 and 2004, equivalent to an increase of 96%.

9.3 Productivity at the micro-level

Measurement of the time used in the production process can be a useful tool in the evaluation of the productivity of a surgical team or unit. Time use in a conventional operating room is typically divided into 1) 'knife time' and 2) 'turn over time'. Knife time is defined as the time during which the surgeon is operating on the patient (the surgeon enters the

start time into the electronic patient record when he/she is ready to begin the procedure, and enters the end time when the procedure is finished). Turn over time comprises a) the time spent preparing for the surgical procedure, such as unpacking the utensils and materials, receiving and anaesthetizing the patient, etc. and b) the time spent ending the surgical procedure, such as clearing away the utensils and materials, awakening the patient, cleaning the room etc.

It was hypothesized that the use of an i-Suite™ operating room would influence time use during surgery. Firstly, knife time might be shortened due to technical improvements. Secondly, turn over time might be shortened as the endoscopic equipment does not need to be transported in and out of the room before and after each surgical procedure – the equipment is already hanging there, ready for use. On the other hand, there might be a learning curve connected to the use of the i-Suite™ operating room that extends both knife time and turn over time, at least in the first period after its establishment. Besides the effects of i-Suite™ on knife time and turn over time, there may also be indirect effects on productivity from changes in the organizational environment.

9.3.1 Methods

It was originally planned to carry out a prospective study, in which *both* knife time and turn over time would be measured during a 14-day period before and again after implementation of the i-Suite™ operating rooms. As this was not possible due to delays in the study, data on knife time were instead obtained from the EPR system of Vejle County (turn over time is not registered in this system). There are discrepancies between the data from the EPR system and the data from the GS due to differences in registration procedures.

The sample representing the period before the establishment of the first i-Suite™ operating room (in November 2002) consisted of data obtained for 2001 and up until October 31, 2002. The sample representing the period after the establishment of the second i-Suite™ operating room (in August 2003) consists of data obtained for 2004. The diagnostic codes for the arthroscopic procedures evaluated were KNBA11 (shoulder/upper arm) and KNGA11 (knee/lower leg).

The sample consisted of 1,877 surgical procedures carried out at Dagklinikken for outpatients from the orthopaedic department at Vejle Hospital (code 01.9) and patients at Dagklinikken (code 01.6). Both primary/most important procedures and part procedures were included. The procedures are unequally divided between the years and procedures, as shown in Table 6. Three-quarters of the procedures, and all of the arthroscopic shoulder surgery, were carried out in 2004.

Table 6. Procedures included in the micro-level productivity analysis

Year	Arthroscopic surgical procedures	
	Shoulder/upper arm (KNBA11)	Knee/lower leg (KNGA11)
2001	0	40
2002 (until November 1)	0	408
2004	324	1,105

Source: Electronic Patient Record (EPR) system, Vejle County

An analysis of knife time before and after implementation of the i-Suite™ operating room was carried out. All procedures are included, this means also procedures where there have only been an opening without further operation. These “procedures” often only take a few minutes.

The results of the mean knife time for Dagklinikken at Give Hospital are compared to the mean knife time for similar surgery procedures at Vejle Hospital as a control group. As arthroscopic surgical procedures are mostly made as part of another surgical procedure, there exist no standard knife time for these kinds of procedures.

9.3.2 Results

Mean and median knife times are presented in Table 7 for the periods before and after the establishment of the i-Suite™ operating room. There appeared to be a decline in knife time between 2001 and 2004 for the arthroscopic knee surgery.

As all of the arthroscopic shoulder surgery was performed in 2003 and 2004, this type of surgery could not be assessed in the before-and-after evaluation. The evaluation was thus undertaken only for arthroscopic knee/lower leg surgery.

Table 7. The use of knife time in all procedures at Dagklinikken in 2001, 2002 and 2004 (descriptive statistics)

Arthroscopic surgical Procedure		Knife time in minutes					
		N	Mean	Std. Dev.	Median	Min.	Max.
Year							
2001	Knee/ lower leg	40	113.95	25.331	110.50	65	176
2002 (until November)	Knee/ lower leg	394	36.32	26.546	30.00	7	185
2004	Shoulder	312	31.61	19.581	26.00	3	120
	Knee/ lower leg	1,097	25.89	22.520	17.00	5	148
Total		1,409	27.15	22.025	19.00	3	148

Source: Electronic Patient Record (EPR) system, Vejle County

Note: The use of knife time includes all procedures, this means also procedures where there has only been an opening without further operation. These “procedures” often only take a few minutes.

Knife time for knee surgery procedures, Dagklinikken

The statistical significance of the changes in knife time for knee/lower leg surgery was tested in two ways³: i) by analyzing the differences between each year, and ii) analyzing the differences before and after implementation of the i-Suite™ operating rooms. The *first* test shows that the difference in knife time between each year (2001, 2002 and 2004) was statistically significant⁴. The second test showed that the difference before (2001 and 2002 combined) and after (2004) establishment of the i-Suite™ operating rooms was highly significant. This means that there was a reduction in knife time from 2002 to 2004⁵.

Further analyses were made and they also showed highly significant differences in knife time⁶.

³ As knife time data were not normally distributed non-parametric statistics were used.

⁴ The analysis was based on the Kruskal-Wallis test of k independent samples with a chi-square result of 251, degrees of freedom = 2, and p=0.000.

⁵ This analysis was based on a more precise test to test the hypothesis that knife time would be reduced during the period 2002 to 2004. A Mann-Whitney test of two independent samples resulted in U=126,926.500 and p=0.000.

⁶ The analysis was based on parametric tests; both ANOVA and t-tests, of a similar magnitude to the non-parametric test results.

Comparing knife time at Give Hospital and Vejle Hospital

The number of arthroscopic knee and shoulder surgery procedures at Vejle Hospital has both been declining in the period 2001-2004 (table 8). The mean knife time for shoulder surgical procedures has increased, while the mean knife time for knee surgical procedures has declined during the period.

Table 8. The use of knife time in arthroscopic knee and shoulder surgery procedures at Vejle Hospital in 2001, 2002 and 2004 (descriptive statistics)

Arthroscopic surgical procedure		Knife time in minutes						
		N	Mean	Std. Dev.	Median	Min.	Max.	
Year	2001	Shoulder	31	49.26	23.531	45.00	20	145
		Knee/ lower leg	99	43.96	29.676	35.00	10	202
2002		Shoulder	30	51.33	23.675	45.00	20	140
		Knee/ lower leg	76	34.51	17.852	30.00	9	90
2004		Shoulder	9	63.33	29.368	55.00	35	110
		Knee/ lower leg	42	35.02	23.383	30.00	5	110
Total			287	42.10	25.599	35.00	5	202

Source: Electronic Patient Record (EPR) system, Vejle County

Note: The use of knife time includes all procedures, that means also procedures where there has only been an opening without further operation. These “procedures” often only take a few minutes.

Comparing the mean knife time for knee surgery procedures in Vejle and Give Hospital shows a higher knife time for the year 2001 at Give Hospital (113.95 minutes⁷ (n=40) vs. 43.96 minutes (n=99)), but in 2002 it is 36.32 minutes (n=394) at Give Hospital and 34.51 minutes (n=76) at Vejle Hospital. In 2004 the mean knife time at Give Hospital is 25.89 minutes (n=1,097) comparing to the knife time at Vejle Hospital (for the year 2005) is 35.02 minutes (n=42).

Comparing the mean knife time for shoulder surgery procedures in Vejle and Give Hospital in 2004 shows a lower knife time at Give Hospital (31.61 minutes (n=312) vs. 63.33 minutes (n=9)). Comparing the knife time for shoulder surgery procedures before and after the

⁷ The mean knife time is very high because there have not been any short procedures e.g. when the surgeon opens without further operation.

implementation of the i-Suite™ operating rooms by comparing the before-situation at Vejle Hospital to the after-situation at Give Hospital shows a lower knife time at Give Hospital (31.61 minutes (n=312) vs. 49.26 minutes (n=31)).

9.4 Discussion

The case-mix at Dagklinikken has changed from 2001 to 2004, with the most marked difference being an increase in shoulder surgery because of the establishment of the i-Suite™ operating rooms. The total number of surgical procedures has more than doubled (161%) from 2001 to 2004 due to an increase in both shoulder/upper arm and knee/lower leg surgery. Dagklinikken has achieved its goal of increasing production by about 80%. At the same time there has been an additional outpatient department line (from two to three), an additional operating line (from two to three), and an additional operating room (from three to four, of which two are now i-Suite™ operating rooms). Furthermore, the number of nurses has more than doubled and there has been an increase of surgeons by 33%.

The design of the productivity analysis is a result of pragmatic considerations, as it was not possible to associate Dagklinikken's surgical procedures between the i-Suite™ and the conventional operating rooms. Therefore, we have used data on the type of procedures mostly made at the i-Suite™ operating room which are arthroscopic surgical procedures in knee/lower leg and shoulder/upper arm.

There has been a decline in knife time for the knee surgery procedures after the implementation of i-Suite™ operating rooms at Dagklinikken. The direct measurement of knife time, based on registrations in the EPR, should give an accurate picture of the micro-level productivity, since it is a measure of the actual input into the production process. On the other hand, time spent in the operating room is only part of a more complex process, which also includes time in the recovery room and other facilities. If, for example, the recovery room is not able to handle more patients as a consequence of shorter operating times, it does not make sense to increase the rate at which the surgical procedures are performed. The reasons for the decline in knife time at Dagklinikken could be many

e.g. better staff cooperation (teamwork), altered working procedures and/or high technology equipment. It was not possible to analyze turn over time between the surgical procedures. Information gathered from the interviews with clinic staff suggested that turn over time could decrease due to the greater ease of assembling and moving the equipment around in the i-Suite™ operating room and in preparation for the next surgical procedure. Other reasons could be a faster working speed and more effective working processes and better arrangements in the operating room.

10. Conclusions

In this case study undertaken at Dagklinikken in Give Hospital there has been made lots of changes in planning and installing the i-Suite™ operating rooms. From the review of hospital documents and the interviews made with Dagklinikken's staff, it was clear that these changes have yielded many effects for the hospital and the staff working in the i-Suite™ operating rooms. These changes have been reviewed under three categories: a) technical changes, b) changes in the physical environment, and c) changes in the organizational environment.

The results of the interviews give rise to several hypotheses related to the conditions or relationships that are influenced in the implementation and use of i-Suite™ operating rooms. They describe the different kinds of changes and the effects on the hospital and the staff. For further research it would be useful to operationalize these hypotheses into measurable objectives e.g. in qualitative studies about work organization and cooperation, supplemented by quantitative time use studies and job satisfaction surveys.

The staff at Dagklinikken considered that the new technology and operating arrangements had produced benefits such as better ergonomics and greater task focus on the part of the surgeons and theatre nurses. A better working environment was a result of greater job satisfaction and improved cooperation both within and between the professional groups. The staff agreed that organizational changes, such as the establishment of operating teams, had been an important part of the implementation of the i-Suite™ operating rooms to ensure an optimal use.

The literature review mostly referred to the advantages and disadvantages of the working environment within a high technology operating room. The results do not differ in the case study made at Give Hospital. The technical improvements and improvement in the physical environment results in an altered cooperation between surgeon and theatre nurse and thereby better working environment and job satisfaction. The surgeon and theatre nurse can better focus on their several tasks and experience less stress during the operation.

The literature review also identified two studies in which knife time was significantly shorter for surgical procedures in minimally invasive surgery suites (modern suites similar to i-Suite™ operating rooms), in comparison to those in conventional operating rooms. Unfortunately, it was not possible in the present case study to undertake a prospective study before and after implementation of the i-Suite™ operating rooms. Knife time was instead analyzed as a micro-level productivity analysis, in which data on knife time were obtained from the Electronic Patient Record system. A comparison of knife time in the years before (2001/2002) and after (2004) implementation of the i-Suite™ operating rooms showed a significant reduction in knife time for arthroscopic knee surgery. The mean knife time for arthroscopic knee surgery have declined from 2002 to 2004 (from 36.32 to 25.89 minutes). In the period 2001 to 2004 the mean knife time for arthroscopic knee surgery has also declined at Vejle Hospital (from 43.96 minutes to 35.02 minutes).

In the present study it was not possible to separately identify the surgery that was performed in the i-Suite™ operating rooms, as opposed to that performed in the conventional operating rooms. It was possible, however, to analyze arthroscopic shoulder/upper arm and knee/lower leg surgery as a separate group – these are procedures that are typically performed in the i-Suite™ operating rooms. This macro-level explorative productivity analysis revealed that the number of arthroscopic knee/lower leg surgical procedures increased by 96% after implementation of the i-Suite™ operating rooms (i.e. in a comparison of data from 2001 and 2004). The number of arthroscopic shoulder/upper arm surgical procedures also increased – by 77% between 2003 and 2004. Compared to the increase in staff by more than 100% for the

number of nurses and 33% for the surgeons the technological and organizational changes at Dagklinikken have been beneficial.

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