Evaluation of the Management of Knowledge in Cardiovascular Perfusion Using the KIPP-Model

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Abstract

Work systems are the organisational units where knowledge is applied to work. They comprise knowledge, information, process and purpose (KIPP) and are linked through organisational channels. The evaluation of these elements as basic subjects of knowledge management is shown here using cases of cardiovascular perfusion. Based on KIPP it can be shown that perfusion work has the potential for the generation of knowledge, but the organisational structure shows potential to improve the dissemination of knowledge.

1 Introduction

Knowledge is commonly defined as capacity for effective action, and learning as increasing knowledge. Increasing the capacity for effective action is one major objective of knowledge management. Nevis et al. (1995) describe three stages of managing this capacity (a) the utilisation of knowledge, (b) the acquisition of knowledge and (c) the dissemination of knowledge. Tools currently available to analyse the status of these three stages are rare. In this paper we use the KIPP-approach (Struck 1998) to analyse the management of knowledge in the environment of open heart surgery.

The environment in which open heart surgery is conducted (i.e. in the operating theatre) plays a critical role in successful operation; the physical layout of the space generally follows routine patterns. However each operation requires specific organisation and transfer of knowledge. The processes by which this organisation and transfer occur relies on shared information across staff and this, in turn, influences communication activities and how equipment is used. Thus there are important issues pertaining to management of technology and to human interaction/communication.

The work system in question comprises a team of four distinct medical professions. While the surgeon performs the vital repair of the heart defect, he/she is supported by four sub-teams of skilled individuals. Each sub-team is a semi-autonomous unit, with their own set of goals and procedures but who concurrently play their part in the interdependent operation team. The sub-teams include: (a) the surgical team (b) the nursing team (c) the anaesthetists and (d) the perfusionists. The latter maintain the circulation of blood around and oxygenation of patient tissues during surgical procedures.

The management of perfusionist knowledge will be the focus of this paper. In principle it is not dissimilar to units in every purposeful organisation. Just as each sub-team has its own specific knowledge, there is a constant exchange of information within each operating team. The well being of the patient relies on the adequacy of the knowledge of the sub-teams and the proper utilisation of that knowledge. The acquisition and dissemination of knowledge in many medical professions, perfusionists among them, still relies heavily on senior-novice training, making these areas of expertise especially interesting.

2 The KIPP-Model

2.1 The Work-System

All human work is managed by a mental model (Frese 1988). This mental model comprises the knowledge a human bears. Work need not explicitly involve machinery or any technical device, but it needs the application of knowledge to be executed (Hacker 1998: p.45). Considering the current shift from manual work towards more intellectual work (Zuboff 1988 :p.76) it is feasible to focus less on the physical interaction between the human and technical part of work systems and place more emphasis on the knowledge both contribute to a work system. This contribution is usually triggered by the information required to achieve a specific goal or purpose. In the case of the perfusionist the purpose is to maintain the clinical stability of the patient throughout the operation.

Thus Knowledge, Information, Process and Purpose (KIPP) can be seen as the primary components of a work

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system. These establish the KIPP-model, as shown in Figure 1, which represents the relationship between knowledge and information in a process aimed at the realisation of a given purpose.

In addition to the realisation of the purpose, there is, in most cases a secondary product of knowledge created during the process. Practical training courses intrinsically encourage learning specific knowledge as the main purpose of a work system, and the produced entity is the by-product. Production environments, on the other hand, place most emphasis on the product but still can create knowledge as a by-product. In both cases this knowledge is incorporated into a feedback loop, which can modify an individual's knowledge.

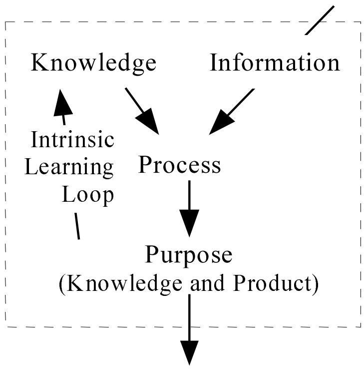

Figure 1: KIPP-Representation Of Work

The Intrinsic Learning Loop in Figure 1 illustrates such "learning by doing". Most practical training courses focus on knowledge acquisition – not product. Most non-training environments focus on product rather than knowledge acquisition. The perfusionist trainee must focus on both as the product (successful bypass) cannot be sacrificed for knowledge acquisition.

The "process" in Figure 1 can be anything which transforms an entity (physical or not) towards a target or purpose. Information, however, needs to be more precisely defined, especially since knowledge can only be shared as information (Morris 1995: p.73). Regardless of the mode of communication (e.g. verbally, e-mail, paper, etc.) the sender of information has to anticipate the receiver's knowledge to maximise comprehension.

In most practical cases the sender will simply assume that the receiver has sufficient knowledge to interpret the information transferred. The receiver has to interpret the information, not only using their own knowledge but taking the sender's knowledge into account as well. Information relates to knowledge in the sense that the better the 'goodness of fit' between the knowledge of the process and its purpose, the less information may be required. For example a highly skilled perfusionist may only need to know the type of heart surgery to construct the appropriate equipment configuration, whereas a novice perfusionist would need some guidance in this.

Apart from information, the product and the process determine the knowledge that is required in a work system. The knowledge about the process may not exceed knowledge about clinical parameters in open heart surgery and their impact on the outcome, the patient's safe condition, making continuous quality control necessary (Bohn 1994).

Knowledge features two dimensions – an explicit dimension, that is knowledge which can be expressed, and a tacit dimension, which usually cannot (Polanyi 1966: p.9). Tacit knowledge describes primary sensorimotor actions and automated routines, which Böhle (1989) connects to experience. As such, these routines represent skill based and rule based behaviour according to Rasmussen's (1983) three types of knowledge. These two types of behaviour require no conscious reflection, in fact such reflection can lead to serious disruptions (Hacker 1998: p.370). Knowledge based behaviour is the third type, which refers to problem solving activities that are subject to conscious reflection, where for example effects of different strategies are considered according to goals through reasoning or testing (Rasmussen 1983). However, these three types establish a hierarchy from knowledge based down to skill based behaviour, where the higher levels incorporates the lower.

2.2 The Work Organisation

Gude and Schmidt (1992) point out that the knowledge applied does not necessarily correspond to the mental model of work it is based on. In particular, skill based behaviour and rule based behaviour do not involve conscious reflection during their performance, thus, unlike knowledge based behaviour, feedback from the task itself may not beneficially modify individual knowledge.

Feedback must be translated and sent through organisational channels. Feedback which has not been transformed into information and communicated to the human participant of a work system will not affect performance. Furthermore, feedback has to be adequate. The present numerical presentation of clinical data in perfusion does not assist interpretation of the values, especially where the impact of those values on the result is not explicitly described, but known by experience.

Organisational channels are represented in Figure 2 as the Outer Learning Loop and External Learning Loop. The intrinsic learning loop represents individual learning, and the shaded information boxes featured in the Outer and External Learning Loop in Figure 2 indicate the points for managerial intervention. The outer learning loop provides feedback from resources within the work-system such as operation team members, while the external learning loop supplies feedback from sources outside the work system. e

Furthermore, workers automate knowledge while learning, thereby releasing cognitive resources for further learning (Koubek 1994).

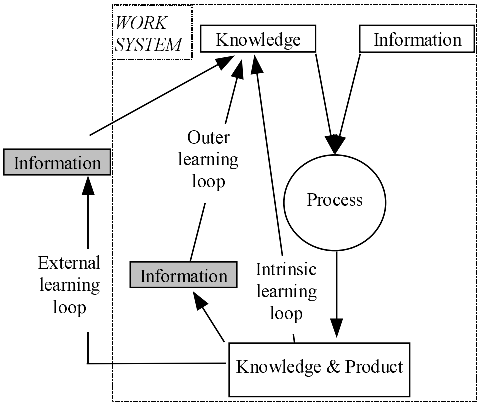

Figure 2: KIPP-Model Of Work

This applies to all levels of knowledge behaviour and means a work system that is supposed to generate new knowledge should more or less constantly challenge people through tasks that require knowledge based behaviour. Additionally, as automated knowledge and routines tend to be tacit, the knowledge is not easily disseminated. However, even if the work itself is subconsciously regulated the application of knowledge determines its procedure and its outcome. The procedure often involves the application of tacit knowledge, which intrinsically prohibits easy assessment, but the characteristics of the outcome are comparatively easy to assess.

Management begins by knowing the state of the object that is to be managed. The state of knowledge acquisition, utilisation and dissemination can be evaluated according to KIPP. For that purpose the tasks of a work system are classified according to the type of knowledge utilised (KBB, RBB, SBB). Further, the assessment of the outer and external learning loops reveals where feedback is given and knowledge disseminated.

3 The Management of Perfusion Knowledge

Open heart surgery is a work system which embodies the utilisation, acquisition and dissemination of knowledge. A perfusionist is qualified by academic and clinical education (Kuruzs 1994). Upon the completion of the academic syllabus a trainee perfusionist enters the clinical environment with a knowledge foundation which mainly comprises explicit textbook knowledge. From this level of knowledge they must learn to operate a heart and lung bypass system from their training experiences in a clinical environment.

During this period the novice perfusionist operates the heart and lung bypass equipment under the supervision of a senior perfusionist for a minimum of 100 cases in order to meet EBCP criteria (European Board of Cardiovascular Perfusion 1991). This form of senior-novice training indicates that a significant amount of perfusion knowledge is tacit and needs practise to become automated or routine.

Perfusionists acquire explicit knowledge from several sources: (a) academic and clinical training; (b) discussions with other perfusionists; (c) conferences and journal papers. The explicit knowledge which is applied to each surgical case by the perfusionist is mainly acquired from literature sources during theoretical training and includes well established scientific facts or procedures. The universal acceptance of a technique in perfusion may be reflected by the extent of its application. The technique for the measurement of ACT (activated clotting time), for instance, is consistent between all paediatric cardiothoracic centres in the UK (Elliott et al. 1993).

Some techniques have become established through the experience of individual hospitals and are therefore accepted as standard only within these hospitals. The less consistent perfusion techniques are not explicit textbook information but tend to be research project or innovative ideas of particular hospitals.

Perfusionists point out that not all hospitals are willing to try these new technologies until they are proven superior. Thus they are less consistently applied. For example, modified ultrafiltration is routinely used by one hospital to minimise the dilution and volume of perfusate in paediatric cases, but it is not yet a universally applied technique because others have yet to be persuaded of the benefits. Although it is currently being introduced to more hospitals, many may not adopt the technique until the benefits are explicitly outlined in standard literature.

Relevant case-specific knowledge is gathered from (a) patient records; (b) pre-operative discussions with the consultant surgeon and (c) pre-operative discussions with perfusion colleagues. This case specific information is combined with established knowledge to devise a strategy for each operation. For instance, the perfusionist will allocate certain component sizes (oxygenator, reservoir, line size) for the circuit based on the height and weight of the patient.

The nature of the heart defect will influence the method by which bypass is carried out. For example, cardioplegia will only be used to arrest the heart in complex and lengthy cases. During each case, a perfusionist acquires and processes information by communication with the other medics and the clinical data presented on various monitors. The perfusionist has the greatest verbal contact with the surgeon, followed by the anaesthetist.

Protocols and observations showed that these are mainly about actions, which take place or have taken place, and the need for adjustments of clinical parameters. Various clinical parameters are displayed in numerical format and continuously updated throughout the procedure and interpreted by the perfusionist. For example, comparing the level of current venous oxygen saturation with the previous one.

Secondly, perfusionists may construct a temporal overview of the venous oxygen level for the duration of the procedure. Thirdly, they consider whether this trend is expected and within safe limits for the current status of the patient.

The perfusion tasks can be divided into three stages (1) pre-operational preparation, (2) the actual surgery, and (3) post-operation activities. These tasks were classified according to the behaviours (mainly KBB, RBB) they demand. Further, the generated information was reviewed in order to estimate the facilitation of the three learning loops.

4 KIPP-Evaluation

4.1 The Utilisation Of Knowledge

4.1.1 Pre-operational Preparation

The following evaluation is derived from data collected during several bypass operations at a hospital in London. The perfusionists receive pre-operative information about the patient, for example the patient physiology, blood group, the nature of the open heart-surgery and the planned procedures (in some cases, for example, the patient heart may be stopped). Information is given about the surgeons and anaesthetists who are assigned to the operation and perfusionists adjust their strategy to the style of the surgeon in charge.

Such strategy design is knowledge based behaviour (KBB). The strategy is derived from explicit knowledge, but perfusionist rely on their experience as well. The observed cases showed that perfusionists integrated devices for modified ultrafiltration according to their positive experience.

Perfusionists configure their means, that is drugs, fluids and technical devices according to this strategy. This configuration comprises, for example, the blood reservoir size, oxygenator size, arterial and venous cannulae and line sizes, and is rule based behaviour (RBB: if-then decisions). The configuration is, however, subject to the surgeons approval, who can demand a change because of surgical necessities.

4.1.2 Operation

The adjustment of means to current surgical procedures is RBB. Obviously, the strategy design aims at stable patient conditions, thus keeping activities during surgery as routine as possible. The process knowledge is typically applied through production rules, e.g. if x then y. This means that parameters describing patient state and displayed on the monitors are treated in terms of threshold for trigger events rather than in terms of detailed physiological knowledge of the patient's changing state.

Bypass parameters, like the ACT-level are monitored and perfusionists adjust perfusate volume or other drug related parameters, like if the ACT-level is above 450 then turn pump suckers on. They also respond to the surgeon's requests, such as "go on bypass".

Nevertheless, any irregularities demand rapid diagnosis (KBB). For instance, a critical bleeding occurred during one observation. The arterial cannulae in place was too small, which the surgeon requested against the judgement of the perfusionist. Remarkably, it happened during an operation where an very experienced perfusionist was in charge. However, such occurrences seem to be rare.

The perfusionists monitor approximately 20 clinical parameters, depending on the case at hand. However, the parameter adjustments involve individual experience. For example, the oxygenation of the blood is judged by its colour. The position of the arterial cannula is tested by the pressure dial swing, which is evaluated by the look of its shape. Some perfusionists turn on the sucker pumps at a significantly lower ACT-level that others. Safe limits are usually designated by individual hospitals, practise, however, varies within individual hospitals.

Perfusionist compile a perfusion record during the operation, where most parameters are recorded in relation to specific events like "re-warm patient" or "added blood".

4.1.3 Post-Operation

The perfusionist's presence at the operation is no longer required when the areteria cannulae is removed. The bypass circuit is disassembled and the perfusion record completed and filed. Post operational tasks require routine RBB.

The patient is then prepared for intensive care. There is little post-operational conversation between perfusionists and other team members. The patient is usually transferred to intensive care, where the perfusionist puts the patient on an ECMO-system (Extracorporeal Membrane Oxygenation) which scans some of the patient's data. This system is operated by intensive care nurses.

4.2 Acquisition And Dissemination Of Knowledge

The outcome in Figure 3 is the patient's condition. This is transformed into related physiological/clinical information that is fed back into the process and controlled by the perfusionist. Information given from other team members and the patient data thus establishes the intrinsic and the outer learning loop. Perfusionists have to interpret trends of the data in order avoid at all or react rapidly to any abnormal situations.

Any deviation from anticipated events needs the interpretation of patient data according to the strategy applied. The perfusionist must interpret the data himself or herself and evaluate whether or not his/her strategy was appropriate. However, there seems to be no other feedback on KBB. The work itself demands knowledge based behaviours, thus features tasks which facilitate the generation of new knowledge.

The ACT-adjustment mentioned above is rule based behaviour. The difference in practise suggests that there is no feedback that is modifying individual behaviour. Different safety limits within different hospitals indicate that there is not sufficient knowledge about the subject. The behaviour is already in a rather automated state, perfusionist usually do not consciously reflect on their action. However, these differences suggest a lack of feedback on a subject that is relevant to the patient's well-being.

The lack of conversation after the operation indicates a insufficient outer learning loop. There is no immediate feedback on actions. Surgeons and perfusionists may apply their experience to the next patient's well-being, but this means a time delay of feedback and in many cases that they encounter different team members, thus feedback would be encountered by different perfusionists.

Perfusionists talk to colleagues about their cases, who in this case would establish the external learning loop. However, there is no systematic approach. It is common practise to file the perfusion record without discussion about the operation. However, the record may include insufficient data to help perfusionists analyse their practise. The dissemination of knowledge is mostly related to irregular events, and are mostly connected to surgery and anaesthetic actions, therefore they are not recorded in the perfusion record.

According to research data presented by Elliot et al. (1993) perfusion strategies vary widely on many aspects, not only between hospitals but between perfusionists as well. This indicates that, based on their training, perfusionist tend to stick to the basic strategies they have been taught but may deviate from them according to unique personal experience. Such practise indicates a well developed intrinsic learning loop, but questions the utilisation of outer and the external learning loop.

Data collected for this paper is insufficient to deliver definitive proof of this, but seems to support Elliot's results. The variation in strategy indicates that there is not enough feedback in order to establish optimal universal practises. Operations are generally not subject to post-surgical assessment.

Furthermore, the individualisation of the perfusion process means that none of the other professions present in the operation theatre can judge the procedural knowledge which perfusionists apply. Their judgement must be base upon the outcome, patient condition, but feedback about procedures applied must come from external sources, which are in this case perfusion conferences or journals and peer group discussions.

Thus, the outer and external learning loop, where knowledge of results can be transformed into information according to figure 2, are not adequately utilised. Further, when information is generated, it is either insufficient (the perfusion record) or verbal, which is not optimal to disseminate knowledge, which explains the strong reliance on experience.

5 Resulting Remarks

Most important for cardiovascular perfusion is the perfusionists strategy. However, there seems to be no feedback on the strategy applied other than a successful bypass-operation that required only routine actions.

Explicit feedback needs the applied strategy to be recorded. Here, the influence of experience (e.g. style of surgeon), and explicit standard knowledge needs to be emphasised (e.g. records, descriptions). The incident with the wrong arterial cannulae hints at least at a rather weak facilitation of the outer learning loop in terms of feedback from the surgeon and dissemination of knowledge from the perfusionist to the surgeon. A post-surgery assessment of the operation should comment on the strategy (i.e. the configuration of devices, drugs and fluids) and thus develop the outer learning loop and can be used as basis for information exchange and discussions through the external learning loop.

The external learning loop seems to rely heavily on the verbal exchange of information, which is prone to misunderstandings, oblivion and the like. Not only knowledge based behaviour, but less salient RBB as well can benefit from formalised feedback. The lack of such feedback is indicated in the example of ACT-regulation. Differences in practise can be facilitated if they are made salient and subject to discussions among perfusionists within a hospital.

Observations suggest that the task of data interpretation during bypass can be cognitively exhausting. The data could easily be integrated and displayed as trends (and numbers) instead of digital number sequences, which is considerably harder to comprehend (Wickens 1992: p.116). The presentation of data as trends could release mental resources and therefore facilitate the acquisition of knowledge.

The alterations suggested above should increase the speed of knowledge acquisition and dissemination. The improvement of technology can release mental resources, but the evaluation of the organisational channels which support the acquisition and dissemination of knowledge judges rather the given learning potential, without indicating any reasonable application for technology, yet.

Further, assuming people have an adequate capability for the job, then learning is a question of attitude as well as opportunity. A lack of discussion between professions is by no means new and can very well relate to an organisational culture, which is dividing rather than integrating.

6 Conclusion

A KIPP-evaluation of the management of knowledge shows reasonable results concerning the utilisation and dissemination of knowledge. As evaluation tools are rare KIPP could potentially be the basis for a comprehensive model. However, the data collection process(es) required to produce such a model are, as yet, undefined. Thus, the example of the open heart surgery given above, may not have represented the full range of data required for such a model. In particular, the information exchange between senior and novice perfusionist could not be studied, but may be the main source of eliciting the explicit or tacit nature of the knowledge perfusionists apply.

The dissemination and acquisition of knowledge is as much a question of attitude as it is one of intellectual capability and opportunity. Some methods to investigate a learning climate are currently being developed. Any method, which tries to investigate the management of knowledge has to take all these factors into account. So far, the main objective of KIPP is to evaluate the potential knowledge acquisition and dissemination based on its utilisation. As such it can be a tool for the management of knowledge.

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