Development of a Failure Prediction Strategy for Imaging Systems

A Study from the Clinical Side of View

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Abstract. Predictive maintenance offers great added value for patient safety, availability and safeguarding the clinical process. Through the exchange of relevant data from networked medical devices, increasingly automated decision-making and early failure prediction are possible. Using the early condition assessment and the maintenance measures derived it is possible to react preventively to these forecasts within the maintenance process. This can lead to the avoidance of cost-intensive and risky system failures.

Various methodological approaches of qualitative and quantitative origin were examined to develop the strategy. Inventory records of the BG hospital group and analyses of the development statuses of various manufacturers for predictive maintenance served as the basis for this. Based on the analysis of the data and various expert interviews, these approaches were evaluated and strategies were designed.

The combination of a manufacturer's solution with in-house measures turned out to be the most promising. The analysis and evaluation are carried out by the manufacturer and can then be used by the clinical engineers. Additional components of the generated error messages are measures for prevention or elimination. As a result, internal hospital expertise and an extended data basis for the evaluation of the system status are initially not absolutely necessary and a failure prediction can be incorporated into the clinical process. This enables an increase in own performance and improved transparency and efficiency.

At present, failure prediction for the clinical side is therefore only possible in cooperation. Through additional measures such as the sensitisation of staff, training and the associated increase in specialist expertise, there is the possibility of reacting more quickly and precisely to failure predictions and of operating predictive maintenance partly in-house. Furthermore, with the help of the strategies developed, an optimisation of the existing maintenance strategy and working conditions within the hospitals can be achieved.

Keywords: Clinical engineering · Evidence-based · Medical device · Maintenance · Management · Optimisation · Prediction · Strategy hospitals development

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1 Introduction

Medical technology is one of the most innovative industries and it is impossible to imagine modern healthcare without it [1]. The development of imaging systems in particular enables ever faster and more precise diagnosis and therapy of diseases. The flip side of technical innovation is the increasing complexity of the systems, which is becoming more and more difficult for clinical engineers to master, as a high degree of specific expertise is required to detect malfunctions at an early stage and remedy them immediately [2].

In the course of the digitalisation and Industry 4.0 that has taken place in recent years, Prognostics and Health Management have increasingly become the focus for the maintenance of medical devices. The focus of this special discipline is on the condition assessment of technical devices and forecasts regarding their further condition development. Industry 4.0 devices are characterised by their networking and data exchange and enable new options for maintenance due to the transmission of relevant data. Suitable maintenance measures can be taken to react to these forecasts at an early stage in order to maintain the functional condition and avoid cost-intensive and risky system failures [3, 4].

A study on the topic of sustainable maintenance showed that corrective maintenance oriented towards failure is predominant despite the progress of digitalisation [5]. It follows that, despite the progress in innovation, there are more and more unplannable failures that impair the maintenance goals of sustainability, availability and patient safety in the clinical context [4]. The expansion of the preventive maintenance strategy is therefore the goal of future-oriented maintenance as well as the quality standards of BG hospital group.

The objective of this study was to evaluate whether failure prediction for imaging systems is feasible on the part of the clinical side and how strategic implementation can take place in the existing maintenance of the BG hospitals. In doing so, it was to be considered which possibilities and advantages arise within the framework of Industry 4.0 for the maintenance of clinical systems and clinical processes.

The initial hypothesis of the study was that the networking and provision of log files and system messages of the medical technology systems lead to a strong gain in information regarding their condition and that a need for timely action for the clinical side can be defined from this. As a result, an increase in the preventive part of maintenance as well as a continuous orientation of the maintenance strategy towards the growing digitalisation can be expected. For this purpose, close cooperation with manufacturers and operators was carried out within the scope of this study.

2 Methods

The development of a suitable strategy for the integration of predictive maintenance was based on an empirical research methodology. For this purpose, an inventory and process analysis was first carried out at the BG hospitals and manufacturers. This represented the current status and included the representation of the equipment park of the imaging systems as well as the recording of the maintenance processes.

With the help of the quantified equipment pool, one type of equipment was extracted and used representatively for the further process. The selection was based on criteria that take into account economic aspects and maintenance objectives. The processes of the BG hospitals and the manufacturers were elicited and analysed with the help of a qualitative analysis in the medical technology department. The aim was to ensure that existing process elements that could be assigned to predictive maintenance were also considered in the strategy development and that new process elements were added if necessary. In particular, the exchange of information with the manufacturers served to consider further possibilities for implementation within the hospital group.

Building on the data analysis and assessment, the strategies were designed. The three approaches to data collection used for this included the use of:

(1) internal company data, which were based on the one hand on documented activities of the clinical engineers in the computer-aided facility management (CAFM) software and on the other hand on internally available documents of the services provided by the manufacturers.
(2) device-side data of the representatively selected device type. This data included occurring system messages as well as measured values of the sensor technology. To include this data in the study, there was a close exchange with the manufacturers and cooperation with the internal IT department.
(3) manufacturer's solutions to consider possible combinations with the in-house medical technology department and the use of these within the clinical environment.

3 Results and Discussion

Based on the inventory, the analysis of the manufacturers and the three approaches, different strategies for the clinical side of view could be extracted.

3.1 Inventory and Data Acquisition

The inventory analysis revealed 520 devices in the category of imaging systems. Due to the importance for emergency care, the cost-intensive maintenance and the high degree of digitalisation with corresponding data density, the computer tomograph (CT) was selected as the representative device type. Further selection criteria were ensuring the availability of the equipment and patient safety.

The process mapping identified three processes from the activity areas of corrective and preventive maintenance. Corrective maintenance was divided into internal and external fault message processing. Preventive maintenance was subject to the process of fault prevention. The external processing of fault reports outweighed the internal processing, regardless of the type of maintenance.

Due to the great importance for patient care, ensuring safe and reliable operation is crucial from the clinical side of view. Downtime is minimised by securing the systems with a full-service contract. The full-service contract always includes automatic data transmission for monitoring the system status. On the one hand, this has the advantage that the data is sent to the manufacturer at an early stage so that the manufacturer can react in time, and on the other hand, it has the disadvantage that the expertise and authority of the clinical engineers on site are kept low. An application of predictive maintenance could not be observed at any of the sites.

The manufacturer defines error patterns with the help of occurring system messages in combination with technical expertise. The system messages served as a data basis and amounted to approx. 10,000 messages per day for a CT. The recognition of these error patterns was done retrospectively by defining specific trigger points. These trigger points show the repeated occurrence of a system message within a defined time interval in combination with other predefined system messages. In some cases, parameter deviations and trends were also taken into account. The evaluation was partly carried out via a data-supported AI. In both cases, a specific message was created, validated and made available to the clinical side. This message is shown in Fig. 1.

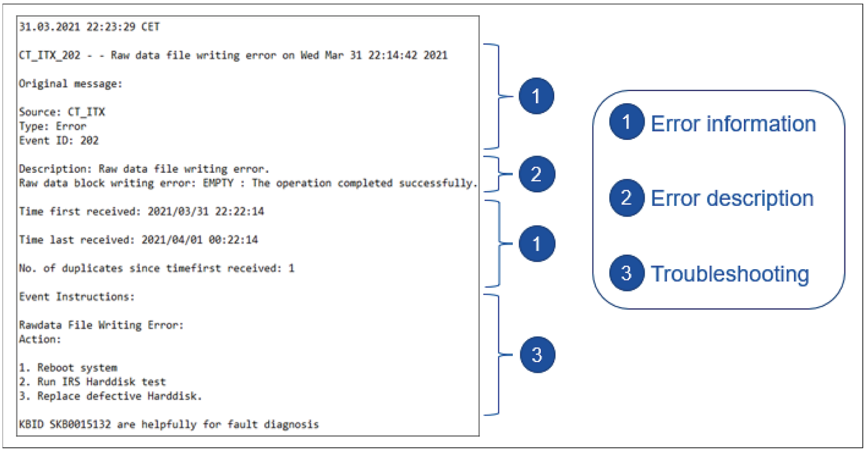

Fig. 1. Structure and content of a predictive message

The approaches listed in Sect. 2 were evaluated based on these findings and showed heterogeneous benefits for strategy development. An analysis of the clinical-internal data for approach (1) was not possible due to the quality of the data. The documented activities as well as the descriptions of failures were insufficient.

The data of the CTs for approach (2) were inaccessible. On the one hand, this data was not made available by the manufacturer and on the other hand, it was not possible to access the data from the CT. A high level of device-specific knowledge is required to view or export this data. The manufacturers are very anxious to develop appropriate models from the data, which will give them a competitive advantage in the market. Therefore, only a very small group of people has access to the data on the equipment side. From various interviews, it became clear that the manufacturers are working on the development of predictive maintenance.

The remaining approach (3), in which the analysis and evaluation are carried out by the manufacturers, therefore seemed more promising. The messages generated in this way proved to be a useful option and can be presented in a web portal or through software implementation in the CAFM system. The messages include both error descriptions and solution steps for rectification. This represents a strategic approach that partly enables internal failure prediction and can be integrated into the daily clinical routine.

3.2 Strategy Development

The error messages generated by the manufacturer can be used by the clinical side with approach (3) and offer a possibility to realise predictive maintenance from them.

The basis for this is the automatic bidirectional synchronisation between the manufacturer and the CAFM system as well as order transfer for the clinical side. The manufacturer's predictive error messages can be continuously displayed in the CAFM system. Further advantages for maintenance are simplified order creation, improved transparency and reduction of documentation gaps. If the web portal were used exclusively, the clinical engineers would have to transfer changes from the web portal to the CAFM system.

The automatic transfer of orders enables more efficient preparation for upcoming maintenance measures. The timely provision and planning of required resources as well as the early consultation with the clinical department should be emphasised here. With the help of this, the maintenance measure can be planned and integrated into the daily clinical routine.

The use of error messages in combination with internal company measures resulted in three strategies for bringing predictive maintenance into the BG hospitals. These are shown in Fig. 2.

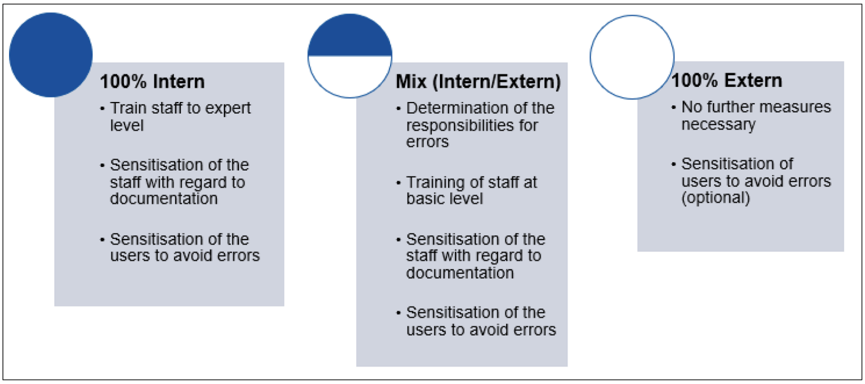

Fig. 2. Variants of the strategy developed for the BG hospitals

This study showed that the specific expertise of the clinical engineers was not sufficient to process a proactive report. The training of the clinical engineers is therefore essential in order to be able to use the error messages. Therefore, it is recommended to train the clinical engineers to the level of a manufacturer's service technician.

In addition, the automatically generated error message can be used as a clue for unknown errors. The clinical engineers should also be sensitised to detailed error descriptions. This also applies to the users to additionally promote data quality. The resulting better identifiable error pattern helps to plan maintenance measures more efficiently and to recognise error patterns in the future. Sensitisation can be achieved with the help of regular instruction by clinical engineers to minimise user errors.

With an appropriate level of awareness, the equipment log data can be used to determine own error patterns, which have been recognised due to the increasing experience. Likewise, a better data scope of internal data would be achieved due to the sensitisations. In combination, this could lead to the competence of own failure prediction in the long run.

A mix of internal and external order processing or exclusively external processing would also be conceivable. If the service is provided exclusively externally, no further measures would have to be taken. The implementation would nevertheless provide the advantages mentioned at the beginning, which in turn would lead to better efficiency and transparency. In the case of a mix of external and internal implementation, the respective areas of responsibility must be defined. In this case, too, the clinical engineers should be trained. Here, however, basic equipment training is sufficient. In future, orders with defined solutions would be processed internally, as would clear error patterns or preventive measures. Orders for more complex faults would then be processed by the manufacturer's service department. The prerequisite for this, however, is a definition of the complexity of the error.

The basic prerequisite is a continuous connection to the manufacturer's service. Monitoring of the interface should be carried out by the manufacturer to ensure data transmission.

4 Conclusion

In this work, a strategy for the clinical-side implementation of predictive maintenance was developed.

The high demands on reliable failure prediction quickly led to the limits on the clinical side. Identifying faults before they occur and proactively counteracting them cannot be implemented without constant support from the manufacturers. For this, a high level of device-specific expertise and open access to device data are indispensable.

It is also clear that for the manufacturer this data is important to the company. It is used for service planning as well as for the development of new equipment and service products, and it reveals a lot about how the system works. It is therefore understandable that manufacturers are not interested in disclosing this internal information. Analyses and evaluations by clinical engineers are not planned at this time.

With the help of the developed strategy, which is a combination of a manufacturer's solution and internal measures, a failure prediction can be carried out as far as possible. It is possible to work in cooperation with the manufacturer and reduce the dependence on the manufacturer. Complete manufacturer independence can be ruled out due to the shortage of skilled workers and the increasing requirements. With the help of the specific expertise that has been built up accordingly, decisions and questions can be analysed and made independently.

Staff training and awareness-raising are important in this respect. These measures are aimed at increasing in-house performance so that the outsourcing of services is reduced. The additional functions in the CAFM system also improve working conditions.

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