

A Regional Review of Flexible Endoscope Service Delivery Models and Preventive Maintenance Practices

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Abstract—While the literature surrounding flexible endoscopes predominantly focuses on disinfection and sterilization processes, there is a notable lack of guidance on managing these devices beyond reprocessing. This paper examines the broader role of the Biomedical Engineering (BME) Department in managing flexible endoscopes throughout their lifecycle. A regional review of service delivery models and preventive maintenance (PM) practices was conducted across 24 healthcare sites in the Lower Mainland of British Columbia. Using work order data extracted from the Computerized Maintenance Management System (CMMS), along with insights from site visits and interviews with BME technologists, Medical Device Reprocessing Department (MDRD) staff, and clinical teams, the study revealed crucial yet inconsistent BME involvement, variations in PM practices, gaps in data tracking, and communication barriers between departments. These findings highlight the need for clearer processes and guidance from a clinical engineering perspective. Practical recommendations are provided to address these gaps, focusing on standardizing workflows and defining the roles where BME provides the most value in flexible endoscope management.

Keywords— Flexible Endoscopes, Preventive Maintenance, Clinical Engineering, Healthcare Technology Management

INTRODUCTION

Flexible endoscopes are essential tools in healthcare, used across healthcare departments for diagnostic and therapeutic procedures. These devices have complex, multi-layered structures with delicate optical, electrical, and mechanical components. Their reusable nature makes them particularly prone to damage during use, reprocessing, and storage [1, 2].

While extensive literature exists on disinfection and sterilization processes [1, 2, 3, 4], there is a noticeable gap in guidance on other critical aspects of lifecycle management, such as preventive maintenance (PM), repair coordination, and overall oversight. This gap leaves BME departments without a defined framework to effectively support these devices.

BME departments have a vital role in managing flexible endoscopes by providing technical expertise and logistical

support throughout their lifecycle. However, their involvement varies significantly across healthcare sites, often influenced by differences in workflows, available resources, and reliance on external vendors. Some facilities depend on Original Equipment Manufacturers (OEMs), while others turn to third-party vendors for inspections and repairs.

In British Columbia's lower mainland region, the Lower Mainland Biomedical Engineering (LMBME) Department supports the maintenance of flexible endoscopes across four Health Authorities (HAs). However, these practices are inconsistent across HA and sites. PM schedules are often applied inconsistently due to the perceived lack of necessity, as scopes are frequently sent to vendors for repair. Furthermore, the quality and consistency of work order (WO) documentation in the CMMS vary widely, hindering the ability to assess maintenance effectiveness.

This study evaluates service delivery models and PM practices across 24 healthcare sites within these HAs, focusing on flexible endoscopes listed in their inventory. By analyzing CMMS WO data, conducting site visits, and interviewing key collaborators, this research identifies major challenges and proposes actionable recommendations. The aim is to enhance operational efficiency, standardize workflows, and clarify the role of BME in flexible endoscope management.

METHODS

The study focused on healthcare sites with Risk 2 flexible endoscopes, which are classified as medium-risk devices under the provincial BCBME framework [5]. These devices were selected due to their high clinical utilization and the complexity of their maintenance requirements.

The methodology combined quantitative data analysis and qualitative insights to evaluate service delivery models, PM practices, and the involvement of the BME department in managing flexible endoscopes across healthcare sites.

Site Visits and Observations

Site visits at multiple healthcare facilities provided insight into endoscope management processes, interdepartmental interactions, and clinical context to better understand operational differences across sites. Observations of the Medical Device Reprocessing Departments (MDRD) and clinical areas provided firsthand observations of workflows, including decontamination, reprocessing, and handling of flexible endoscopes. These visits also explored how issues were flagged and identified for repair. Tours of BME departments offered an understanding of how PM and inspections were performed on endoscopes. Informal discussions with staff during these visits highlighted challenges and perceptions of the BME department's role in endoscope management.

Interviews

Interviews were conducted with key collaborators across multiple departments and vendor representatives to gain insight into current practices and challenges:

1. **BME Department:** Discussions with technologists and supervisors explored their roles in PM and corrective maintenance (CM), challenges they encountered, and their perspectives on current practices and potential improvements.
2. **MDRD:** Interviews with MDRD staff focused on reprocessing workflows, communication with BME, and perceptions of BME's role in flexible endoscope management.
3. **Clinical areas:** Endoscopy nurses and Clinical Nurse Educators shared feedback on flexible endoscope handling, communication protocols, and their perceptions of BME support in maintenance and repair processes.
4. **Vendors:** Representatives from an OEM and a third-party company provided insights into best practices, service contract options, and challenges observed in flexible endoscope management.

Surveys

Surveys were distributed to sites where in-person visits were not possible, broadening the scope of data collection. These surveys focused on PM practices, repair activities, documentation processes, and training related to flexible endoscopes. Respondents were also invited to share suggestions for improvement and highlight best practices observed in their departments.

Thematic analysis of interview and survey responses identified recurring issues such as inconsistencies in PM prac-

tices, challenges with data tracking in the CMMS, gaps in interdepartmental communication, and varied perceptions of BME's role throughout the lifecycle of flexible endoscopes.

Data Analysis

WO data were extracted from the CMMS to quantify maintenance activities and analyze trends over the past decade. Only WOs explicitly categorized under PM or CM were included to focus on maintenance-specific activities. Inconsistencies in WOs, such as missing fields or illogical dates (e.g., completion dates listed before the start date), were identified and corrected during data cleaning and filtering.

PM and CM ratios were calculated by dividing the total number of CM or PM WOs by the total number of work orders for each endoscope. Mean Time Between Failures (MTBF) was determined by calculating the number of days between successive CM WOs for each asset. The data were normalized to enable comparison across sites. However, the analysis acknowledged the potential for classification errors and missing data, which may have influenced the results. These challenges highlight the importance of establishing consistent data collection and documentation practices moving forward.

FINDINGS

The findings are categorized into qualitative and quantitative results, providing a comprehensive overview of flexible endoscope management practices and maintenance trends.

Qualitative Findings

Qualitative insights revealed substantial variability in PM practices and BME involvement across sites. Key observations include:

1. **Role of BME:** BME involvement ranged from comprehensive roles such as post-repair inspections and troubleshooting to minimal roles limited to shipping and receiving endoscopes for repair. One site had no BME involvement in its flexible endoscope fleet at all. Core responsibilities across all sites include investigating patient safety events, WO documentation, and inventory tracking. This variability is influenced by service agreement types (e.g., OEM full-service contracts, pay-as-you-go services, or third-party repairs). Aligning BME roles with contract types could optimize resource use and maintain cost-effective practices.

2. **Communication gaps:** MDRD and clinical staff reported delays with BME, particularly for scopes requiring repair. These delays were attributed to unclear workflows, bottlenecks in approval processes, and high workloads at smaller sites with limited BME technologist availability.
3. **Perceptions of PM value:** PM schedules, guided by the provincial framework, classify most flexible endoscopes as Risk 2, requiring annual maintenance. However, the floating PM schedule system often results in irregular intervals between maintenance tasks, driven by staff availability and workload. Frequent repairs can render PM seemingly redundant for recently serviced scopes. Practices also vary significantly between sites; some rely on post-repair inspections recorded as PM, while others perform PM during clinic downtimes. Additionally, manufacturers provide limited actionable guidance for PM schedules, complicating standardization efforts.

Survey responses from BME staff reinforced these findings, emphasizing challenges in maintenance tracking, resource allocation, and inconsistent PM practices across sites.

Quantitative Findings

WO data analysis revealed several trends:

1. **PM and CM ratios:** Across all sites, PM WOs were consistently underrepresented compared to CM WOs, with some years recording no PM activity at all.
2. **Correlation Analysis:** A Pearson correlation coefficient of 0.36 between PM and CM WOs indicates a weak positive relationship. This suggests that increased PM activity might correlate with higher CM reporting, potentially due to increased scrutiny during PM activities. However, the result is inconclusive due to the absence of PM work orders in several years, reducing dataset reliability.
3. **MTBF:** MTBF analysis revealed that most flexible endoscopes fail before 365 days, with an average MTBF of 345.11 days. HA 3 had the highest MTBF at 382.82 days, while HA 2 had the lowest at 198.07 days (Figure 1). These variations reflect differences

in usage patterns, maintenance practices, and procedural volumes across sites.

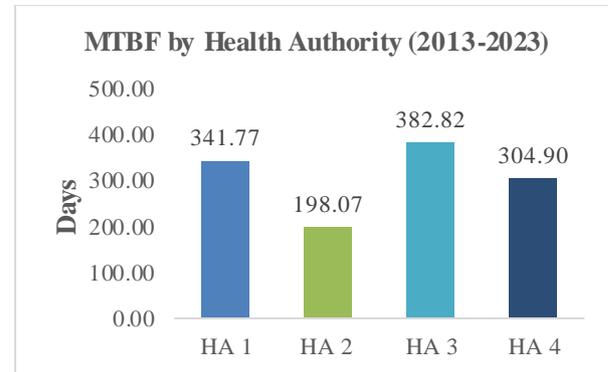


Figure 1: Mean Time Between Failures (MTBF) for flexible endoscopes by Health Authority (2013-2023).

DISCUSSION

The analysis exposes significant gaps and inconsistencies in flexible endoscope maintenance practices across HAs. With most scopes failing before 365 days, it is clear that the current annual PM schedules are not enough to prevent corrective maintenance. Additionally, PM activity does not appear to consistently reduce CM rates, as years with more PMs did not see fewer repairs, and years with fewer PMs did not experience an increase in failures. This suggests that PM, as currently implemented, may not address the primary causes of endoscope failures. Factors such as high usage, improper handling, or reprocessing practices may play a larger role in driving failure rates.

Irregular PM compliance and incomplete WO documentation further complicate the evaluation of PM effectiveness. For example, scopes sent for repairs often bypass scheduled PM, and inconsistent recording of maintenance activity obscures trends, making it difficult to draw reliable conclusions about the relationship between PM and scope reliability.

HA-specific trends highlight additional challenges. HA 2, with the lowest MTBF, struggles with aging fleets and reliance on non-OEM parts, which likely contribute to more frequent failures. On the other hand, HA 3's higher MTBF suggests better maintenance practices or fewer procedural demands. These differences underline the need for maintenance strategies tailored to actual scope usage and local conditions.

These findings align with the feedback from BME staff, who reported reactive roles, unclear responsibilities, and insufficient training. These limitations hinder their ability to proactively manage endoscope maintenance and contribute to broader inefficiencies in workflow and communication.

To bridge these gaps, clearer PM protocols, standardized documentation, and improved communication among BME, MDRD, and clinical teams are essential. These measures can ensure more effective use of resources, reduce unscheduled repairs, and ensure the consistent performance of flexible endoscopes.

RECOMMENDATIONS

To optimize BME involvement in flexible endoscope management, responsibilities should align with areas where their technical expertise is most valuable. These responsibilities span the entire endoscope lifecycle, as illustrated in Figure 2.

Key Areas for Improvement

- 1. Delegate Non-Technical Tasks:** Activities such as packaging scopes for shipping, receiving shipments, and coordinating non-technical vendor communications should be reassigned to appropriately skilled roles. This allows BME technologists to concentrate on their technical responsibilities, such as maintenance and failure diagnostics.
- 2. Prioritize High-Value Activities:** BME's involvement should be concentrated on critical areas, including:
 - Maintenance and Repair
 - Risk Management
 - Training
 - Procurement Support

Additional Recommendations

- **Track flexible endoscope usage** and correlate it with failure rates. This data can refine PM schedules and predict maintenance needs.
- **Perform regular visual inspections** to identify early signs of wear and tear, following ANSI/AAMI ST91:2021 guidelines [6].
- **Develop a centralized, real-time dashboard** to improve communication and coordination between BME, MDRD, and clinical teams.
- **Provide targeted training** for clinical and MDRD staff on recognizing early signs of scope failures.

These recommendations aim to optimize BME's role, streamline processes, and improve the overall management of flexible endoscopes.



Figure 2: Health Technology Management Lifecycle for Flexible Endoscopes. This diagram illustrates the potential roles and responsibilities of BME departments across the lifecycle of flexible endoscopes. *Image modified from the original [7].*

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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