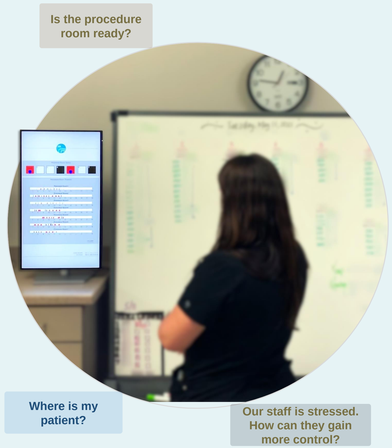
A MEDICAL CYBER-PHYSICAL SYSTEM TO IMPROVE ENDOSCOPY UNIT WORKFLOW VISIBILITY AND INCREASE THROUGHPUT: A PILOT STUDY

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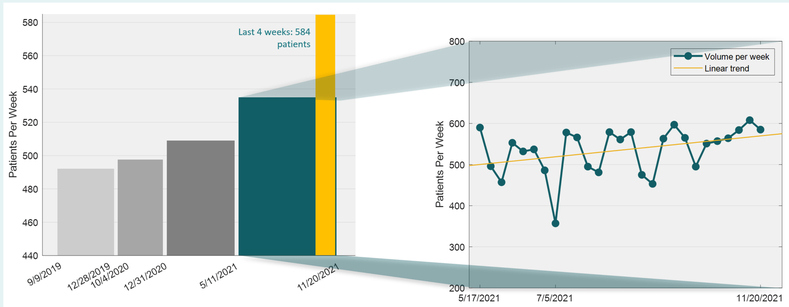
Introduction

Endoscopy units are complex environments with limited real-time staff visibility into activities and situations that impact workflow and efficiency. In large GI Labs, hundreds of medical professionals are active, most facing multiple complicated tasks, high stress, COVID-19 concerns, and different patient care needs. The manager tends to make decisions based on personal experience rather than on facts or data. Consequently, most GI Labs operate at a low efficiency with frustrated staff and leave millions in revenue "on the floor." Optimizing efficiency can not only positively impact throughput but can also improve patient and staff satisfaction. This study evaluates the utility of an automated *cyber-physical* monitoring system (System) to capture key workflow events in a busy outpatient endoscopy center, relay real-time actionable information to staff, and improve patient throughput. This infrastructure provides a step-change in overall visibility and fact-driven support to the managers in their decision process.



Results

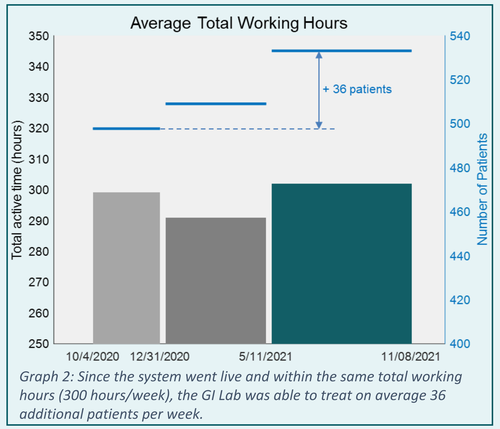
Baseline data was taken from 24,000 procedures and compared to study date from 14,444 patients (Graph 1). Procedure volume, with System monitoring and feedback, increased 8% compared to 2021 baseline data and 12% compared to 2019. This increase in procedure volume was achieved by increasing the efficiency of center utilization as indicated by a net increase of 36 procedures per week without extending the last case completion time of day by more than 15 min (Graph 2) and while decreasing the average time patients spent in preop by 6 min (Baseline 43±1 min; System 37±2 min). The net result was an increase in the center utilization from 78% in early 2021 to 90% at study end with a potential for an additional $150,000 in monthly revenue ($1,050/procedure).



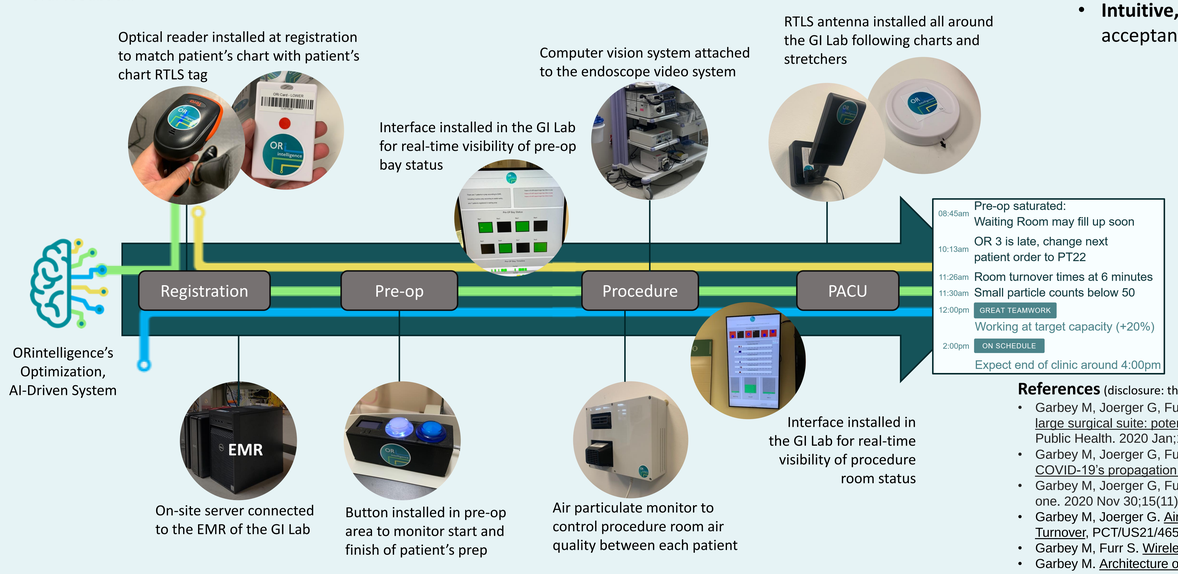
Graph 1: Average volume of patients per week over the four periods analyzed. Grey periods are pre-installation of the System; teal period is after installation of System with the zoomed in plot showing an increase of 12% since start of study.

Method

To address the lack of visibility, ORintelligence LLC (Houston, TX, USA) has developed a fit-for-purpose cyber-physical infrastructure that fills the unaddressed efficiency gap, using adapted sensors and an array of human-computer interfaces. The System was installed in 6 hours by two technicians in a single outpatient endoscopy center with 7 procedure rooms accommodating about 15 patients per day per room. It includes a direct interface to the center's electronic medical record (EMR) and a lightweight network of sensors, displays, and hardware for automated monitoring of patient and procedure workflow as well as real-time communication with staff (Figure below). Baseline workflow data was harvested from the EMR over two periods (9/9/19 – 12/28/19; 10/4/20 – 5/8/21). Data was then collected prospectively from the System (5/10/21 – 11/20/21) including pre/post-procedure patient care times, procedure and room usage times, and air particle monitoring (used to determine room cleaning status). Data impacting the day's workflow was provided real-time to the staff via display monitors and automated text messages. Weekly workflow reports were also provided. Efficiency was assessed by comparing baseline data to System data during the study period, as well as collecting staff observations and oral feedback.



Graph 2: Since the system went live and within the same total working hours (300 hours/week), the GI Lab was able to treat on average 36 additional patients per week.



Conclusion

The systems that are currently used to manage GI Labs are based on subjective decisions, disconnected to the reality, contain errors, and are not people-friendly. Real-time data analysis can provide true process visibility and actionable information to enhance workflow and improve efficiency. The automated cyber-physical system utilized in this study enabled an increase in procedural volumes and shorter patient in-facility times without extending the staff's workday. The increased monthly revenue derived from this efficiency provides a powerful return on investment and justifies the cost of installation and use of the System.

Take away message:

ORintelligence developed a **software and hardware solution** to optimize **efficient scheduling** and **coordination of surgical suite resources** combining:

- **Accurate and non-invasive real-time acquisition of essential workflow events** based on proprietary sensors and signal processing techniques linked to the EMR. Our system tracks tasks, not staff, and even corrects select EMR input values or gaps, which has a 20% inaccuracy rate.
- A **digital twin of the clinical workflow** that takes the daily input from the EMR and the sensors and will be the foundation of an advanced heuristic computer reasoning engine
- **Intuitive, flexible Human-Computer Interfaces** that raise technology acceptance and respond/adapt to end-user feedback

Future Directions

This study is a first step in increasing the awareness of the staff by giving them the right information at the right time. ORintelligence is now continuing the development of its cognitive computing driven approach for GI Lab management. To further assist the manager in clinical decision making, the system requires a sentient part. ORintelligence is developing the architecture of a HEuristic Reasoning ALgorithmic Development (HERALD) system that can support and inform the surgical suite manager and dramatically improve their efficiency in making clinical decisions. With accurate timestamps and user feedback, the engine can suggest near-term and long-term actions to help reach higher revenues, greater staff/patient satisfaction, and more control. It will learn autonomously, day after day, to improve itself by running continuous digital process analogs to "thought experiments" using a digital twin model of the facility.

References (disclosure: this study was funded by Boston Scientific)

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