In both the inpatient and outpatient settings, Massachusetts General Hospital (MGH) had been struggling with space issues for years, and by 2000, it had reached a breaking point. There was sustained pressure to add 50,000 to 100,000 square feet of clinical and administrative space. After years of constrained growth, MGH Ambulatory Care was estimated to have a need for as much as 400,000 square feet, which, when combined with projected increases in outpatient visits, would rise to nearly 600,000 square feet in 2005 and beyond. In response to the overwhelming space need, facility leaders committed to the construction of a new ambulatory care center. The capital was set aside, and plans for the new Yawkey Center for Outpatient Care (YCOC) were drawn.

In a time of tight budgets and slim operating margins, the new center was going to consume a considerable portion of the capital budget for a number of years, with a price tag of about $200 million. The building had to be efficient and generate revenue in short order. Existing models of patient care and space allocation would not...
generate the necessary returns to meet these objectives. New thinking was required across the board.

MGH Real Estate Planning devised a set of occupancy principles to help guide and shape the changes that were needed. First was a focus on the patient, providing easier access while minimizing the number of destinations per visit. Second was a focus on collaborative and multidisciplinary practices, particularly those best suited to serve established patient populations. And finally, there was a focus on cost-efficient design, with larger practice suites, standardized offices, and exam room square footage, with shared support space including waiting areas and ancillary services such as phlebotomy.

For the YCOC to be viable, internal studies and simulations showed that the primary keys for success would be maximizing the amount of discrete available clinical workspace through systematic planning and increasing the number of patients seen, without becoming overwhelmed. REP worked with members of clinical operations and finance staff to model potential appointment volumes and revenue requirements against departments’ square footage requests and the physical constraints of the YCOC’s footprint.

Standardized practice areas, each with 15 clinical exam rooms and shared support spaces across practice areas, appeared to be the most efficient layout. Patient throughput would be maximized by level scheduling, the concept of coordinating clinician and department hours of operation to evenly distribute patient visits throughout each hour of the day and across each day of the week.

Workflow Enabling Software

Being the third oldest hospital in America, MGH has grown to its current 25-acre size in fits and starts over the decades, and space has been reallocated and redesigned as medicine, staff, and technology changed. Portions of the campus are cramped, outdated, and inefficient for the practice of modern medicine.

However, these close quarters provided support staff with line-of-sight viewing of the waiting area, exam room, clinician, and patient. There were other various combinations of telephones, intercoms, and overhead paging systems to augment communication within the practice. These technologies often were distracting to clinicians and patients and not appropriate in the environment that followed the enactment of HIPAA privacy regulations. New technology and tools needed to be created to accommodate larger practice areas, higher patient volume, and privacy requirements.

A project team, composed of ambulatory care administration, IS, and outside consultants, was assembled to try and define the functional requirements of a tool that would support operations, communication, and workflow in the new building. The project team engaged the departments scheduled to move into the YCOC by holding focus groups to define initial tool specifications.

The results of the focus groups were surprisingly uniform. Although the practices shared little in the way of current common processes, and despite being asked to define a set of optimal conditions for an environment they could not see, a set of broad themes did emerge. The major features of the new tool involved both operational and reporting functionality.

In terms of operational functionality, the focus group wanted an application that enabled patient tracking, providing the ability to see a patient’s location at any point in time, current and historical within the practice’s area, and care areas within other departments. It sought an application that was readily available on all computers throughout the practice so staff could review and interact with minimal effort.

An ideal application also would work in real time, with no lag in updates from external systems or user interaction. Data entry would not be required, because the tool would populate itself with patient appointment data from external scheduling systems while providing an easy user interface to add operational notes. And it would enable time tracking and an audit trail to provide comparisons between specific events, such as scheduled appointment time, and the patient’s actual arrival time.

In terms of reporting functionality, the application would be able to identify bottlenecks in ancillary services; enable MD productivity through queuing; show room usage; enable duration calculations for waiting times, durations of visits and the like; and provide data for time tracking and audit trails.

With a set of high-level functional requirements defined, the project team developed a set of scenarios that described how end users would utilize the tool. These scenarios documented tasks the users would be expected to perform, events the tool would be expected to capture, and how users and tools would interact. These scenarios also provided a metric with which to evaluate any potential solutions.

Potential scenarios included:

A single appointment in a practice. This scenario covers the majority of expected patient encounters and demonstrates the most basic needs.

Multiple appointments or treatments in a practice. This scenario explores a more complex visit, as might exist with nurse practitioners, Fellows Clinics, or with embedded ancillaries, such as phlebotomy or a cast room.

Single appointment in a practice, with another MGH destination. This scenario expresses the desires of management and practice staff to better understand the relationship between various departments.

Multiple appointments or treatments in a practice, with an interim visit to another practice. This scenario
represents the most complex scenario, where operations in one department are dependent on an unaffiliated area. These can lead to lost or missing patients and unplanned saturation as patients return from off-site unexpectedly.

In addition to being able to visibly depict the status of each patient as they travel through a visit scenario, there was a requirement to show the same “real-time” status for groups of patients, such as for the entire practice or for an individual clinician’s schedule.

The scenarios were presented to several vendors through a Request for Information, and interested parties were invited to visit the MGH campus and demonstrate their product offerings. The project team received several responses, and after further discussion eventually viewed product demonstrations from two vendors.

While both products were presentable, neither struck a chord with the review committee, which consisted of practice staff from each of the future YCOC departments. Both products were reminiscent of inpatient bed-boards, with displays mostly limited to formatted lists and with a focus on integrating clinical systems with results. The applications seemed more appropriate for acute care environments rather than the high-volume ambulatory care population expected in the YCOC. Assessed in light of the scenarios, the focus group determined that the greatest need was for a system that tracked patients in time and space throughout their appointments.

In-house Development

At this stage, an enterprising group of IS staffers decided to take up the challenge and see if they could “bid” on the job. With 20 months to go before the new building would open, there seemed to be a reasonable amount of time to develop a solution internally. The IS team, having the luxury of participating in months of information gathering and viewing inappropriate vendor solutions, embarked on a two-week crash-course effort to develop a mock-up. The mockup would be a façade, showing the desired functionality, without any real foundation.

Using stolen moments and lunch breaks, and selecting tools on the basis of rapid development rather than the capability of being deployed systemwide, a solution emerged, and plans were made to demonstrate it for the review committee. The IS team distilled the functional specifications to their basic parts—patient lists with various sorts and filters, a visual representation of the practice space and exam rooms, and extensive time stamping, which would provide the data for any necessary reporting.

The review committee was given a demonstration of the IS team’s creation. The team explained that mockup was not usable, and there had not yet been appropriate research into the technologies needed to support the proposed application; as a result, there was a reasonable risk of failure if the review committee voted to move forward with it. Despite the warnings, it was well-received; the IS team had captured the essence of users’ needs, and the IS team was urged to bring it to full realization. The YCOC Patient Tracking application was chartered.

Making it Real

Patient Tracking would become the YCOC’s central nervous system and would control a significant portion of the hospital’s ambulatory population through its 600,000 visits per year. A formal project was initiated with all of its necessary components—a charter, a steering committee, a development team comprising functional and technical staff, user groups, and project plans.

An intermediate goal of a fully functional prototype would be piloted for two weeks with subsections of three practices destined to move to YCOC after the construction was completed. The pilot user groups would include 148 staff and 260 appointments per day from portions of Orthopaedics, MGH Vincent Obstetrics Division, and the Women’s Cancer Program.

MGH and its parent corporation, Partners Healthcare System, is primarily a Microsoft shop, and the initial design and expected volume of use appeared to fit nicely with their offerings. It would be a three-tier design, with a Microsoft Internet Explorer front end, Internet Information Server as the Web server, and SQL Server 2000 as the database backend, with SQL Stored Procedures serving as the business logic repository.

To ensure high availability and greater response time, two IIS servers would be used and housed behind a load-balancing content switch that would evenly distribute user activity across the two servers. The user interface would be Web-based drag and drop using DHTML and JavaScript, a framework empirically proven to be robust within the MGH/Partners environment in several other projects. With the technology and tools chosen, the team was free to proceed on turning functional requirements into functioning software.

The focal point of the application would be the user interface, and the design goal was to have a single main page that would enable any user to get instantly a snapshot of the current state of the practice. With minimal effort, the user could drill down into detail or make status changes as necessary.

The main page was split into two sections horizontally. The top half (Figure 1—Appointment Worklist) would provide customizable patient lists and indicators to enable communication about the status of patients and their visits between practice staff. The left and middle of the appointment worklist shows information about a patient and the appointment. The data fields are standard across all departments, and consist of location, the current location of the patient; time, the scheduled appointment time; time in location, or TL, how long the patient has been in this
location, which will turn red if a predefined threshold is exceeded; elapsed time, or ET, an indicator of how long the patient had been at the clinic, adjusted for patients who arrived early, late, or spent time outside the department; an exclamation mark, representing a system-generated alert, noting appointments with unusual features, such as those that were scheduled on the current day, alerting staff that charge tickets and labels may not have been prepared in advance; patient’s name; medical record number; visit type, such as new or follow-up; provider, the clinician with whom the patient is scheduled to meet; and the department or practice with which the visit is associated.

The far right side of the appointment worklist shows indicators, which are multi-value toggles that practice staff can use to communicate the status of patients during their visits. The indicators are customizable by department; for example, in the obstetrics practice, it facilitates communication with the following options: ready for provider; need X-ray; need interpreter services; need/status for ultrasound; vitals checked; and free text notes, such as “patient is upset” or “provider is running 20 minutes late.” The lists are filterable and sortable, enabling practice managers to view the entire practice, while the phlebotomist could watch for patients needing blood draws, and physicians could focus on their own panel of patients.

The lower half of the main page (Figure 2—Practice Layout) would provide a graphical layout of the practice area showing both actual and conceptual locations. The bottom of the section contains a representation of the physical spaces in the practice, such as exam rooms and clinicians’ offices.

The application gives users the ability to design a layout
reasonably close to the actual structure, using room numbers and color schemes matching the existing signage. On screen, patients could be dragged from the appointment worklist into a room, or from room to room in practice layout, to chronicle their movement during visits.

The upper half of the practice layout would be used to show conceptual areas and other useful aggregates of patient data. For example, many practices would have a phlebotomist to draw blood, but not a separate waiting area. A conceptual “blood draw area” could be set up to differentiate between patients in the waiting room waiting for their visit to begin and those waiting for a blood draw. In this example, the phlebotomist could filter their appointment worklist to only show patients with a location of “blood” and have an up-to-date view of all patients waiting for services.

“Within just a few weeks, the application had enabled the practices to start changing operations; in one practice, it virtually eliminated phone calls from the front office to the back office.”

From a reporting standpoint, every action taken or noted in the system would be archived in a time-stamped audit trail. The development team would create an initial set of reports to enable practice managers and administration to aggregate data on a daily, weekly, or monthly basis on various topics such as room utilization, average lengths of visit sorted by provider or appointment. The data would eventually be stored in a data warehouse, enabling users to perform detailed analysis on virtually every facet of each practice in the YCOC.

Checking Progress

As software development progressed, the functional analysts designed an evaluation survey to gauge the usefulness and success of the system. The prototype needed to demonstrate that the development team could deliver functional software and that users would be comfortable using the product. At the end of each two-week pilot, practice staff and management were interviewed about the system, and asked to evaluate it on a range of criteria. The application was rated on the following:

- **As a process tool.** Did the application provide the ability to conduct retrospective analysis as a means to recommend process changes or resource allocation measures and identify bottlenecks?
- **As an efficiency tool.** Did the application increase the efficiency and proper utilization of staff? Was more time spent supporting clinicians and patients and less time looking for patients and empty exam rooms?
- **As a quality enhancement tool.** Did the application improve the quality of the patients’ experience through reduced waiting times and more accurate expectation setting?
- **As a staff satisfaction tool.** Did the application provide staff with increased accessibility and information throughout the patient’s visit?
- **On usability.** Is the system user-friendly and intuitive?
- **On compliance.** Was the system used, was it used in the intended manner, and were the benefits worth the effort?
- **On staff perception.** What do staff, management, and clinicians believe to be the pros and cons of the system?

The Prototype Pilot

By December 2003, three months after getting approval to move forward, the prototype was ready to go. Code had been written and tested, the dictionaries and data tables filled out, the users identified, and the room layouts uploaded. One week after another, the sub-practices were brought on, and they put the application through its paces. Project team members were on-site during each practice’s two-week cycle so that they could train, observe, and document.

At the conclusion of each practice’s pilot, the project team interviewed numerous employees including staff, management, and clinicians, and requested they complete the evaluation survey. The user response was overwhelming positive. On a scale of 1 to 5, with 1 being the highest, the application consistently received scores of 1 or 2 for each question on the survey. During interviews and observations, the majority of users reported that the application was easy to learn, limited the time practice staff spent walking around looking for patients, providers, and rooms, and increased their awareness of patient arrivals, locations, and waiting time.

Within just a few weeks, the application had enabled the practices to start changing operations; in one practice, it virtually eliminated phone calls from the front office to the back office. One particularly interesting workflow lesson reported by all three practices was that the application may have added too much visibility. Medical assist and clinical staff had instantaneous knowledge of a new patient’s arrival and would often come forward to collect the patient for treatment before administrative details, paperwork, co-payments, and other details were completed.
Perhaps the most telling indicator of success was that all three pilot groups asked to continue using the prototype, understanding that there would be no enhancements and limited support. The groups continued using the prototype until they moved into the YCOC the following October.

Getting Ready for Prime Time

The success of the pilots proved that the concepts and features were meaningful, and that the tools were usable and offered enough tangible benefit that staff would actually use them.

“Tracking would become the YCOC’s central nervous system and would control a significant portion of the hospital’s ambulatory population...”

Based on the successful outcome, administration officially sanctioned full-scale development of Patient Tracking and authorized a rare mid-year capital release to fund it. While the prototype was fully functional, the production application would need to scale dramatically to support more than 1,200 daily users and as many as 7,000 managed appointments per day. In addition to battle hardening the software, developers needed to further develop a user-friendly configuration and reporting functionality.

Software development, enhancement and testing continued through the summer of 2004 and wrapped up at the end of August. September was set aside for user training and go-live preparation, coinciding with the YCOC’s opening in October.

Speedbumps at Go-live

On October 12, 2004, Patient Tracking went live as the Phase I departments occupied the YCOC. The doors opened to patients and staff of the cardiology, orthopaedics, pediatric ambulatory care, radiology, rheumatology, OB/GYN, and women’s health departments.

Almost immediately, Patient Tracking experienced response time issues. Project team members stationed around the building and the go-live helpdesk were besieged with calls. The tracking application was slow and getting slower and, in several cases, was simply unresponsive. On the technical front, the development team immediately began to see degradation in the SQL database performance. Frequent rebooting of the SQL server temporarily improved conditions but it was only a short-term fix; it was apparent that there were one or more significant undiscovered design flaws.

The team embarked on an urgent effort to identify problems and improve performance. Because the problems could not be duplicated in the test or quality assurance environments, the team was put in the difficult position of trying to diagnose the problem and develop a solution while still supporting the users on the crippled system. The application had become a single point of failure, and needed to remain “up” while the investigation proceeded.

As the hours and days passed, users were understanding, but their patience began to wear thin, and pressure for a resolution grew stronger.

A complete review of user interface performance, Web server response, and database server capacity was initiated. In addition to using the performance monitoring diagnostics embedded within IIS and SQL, the team developed several tools and diagnostic processes, intended to help isolate issues and provide long-term benefit for ongoing support. The most useful of these consisted of a route and time tracker, which displayed on the user interface the execution time and path through the content switch and associated Web server of any query associated with a user action or automatic refresh. This enabled users or staff to document specific events and states as the investigation continued. The research eventually found response issues within the SQL database as the primary problem.

The team worked on the database structure and the content of the SQL-stored procedures used to deliver data to end-users. As the team studied the performance metrics coming from the SQL database, a number of trouble points became clear. First, it became apparent that user connections were not disconnecting from the SQL server after the user interface had been refreshed or a user completed a patient movement task. These orphaned connections would accumulate and stress the SQL server with their overhead requirements before eventually terminating.

Secondly, the response time of the queries themselves that collected an individual user’s appointment list also was surprisingly slow. What was expected to be a sub-second response was taking multiple seconds, and in aggregate was throttling the system. Thirdly, the real-time appointment interface from the main scheduling system was overwhelming the application. Non-current day appointment activity, such as adding or canceling future appointments, provided a much higher volume of activity than expected.

A final problem was found with the content switch itself. Rather than distributing the load across the pair of servers, the content switch was misconfigured so that users and Web servers were bound together, which negatively affected the application’s performance. This problem was difficult to detect and impeded the investigation effort by introducing unexpected behavior.

The application had undergone performance testing using industry standard tools intended to simulate the
maximum number of potential users, in addition to full rounds of functional and integration testing. A number of factors led to deviations that created a simulation environment significantly different than the real world. First, there was a limited number of concurrent licenses available for the performance-testing tool, which was from less than half of the project team’s maximum projections. Second, the graphical drag-and-drop nature of the application made it very difficult to simulate moving patients from room to room. Finally, the primary inbound appointment interface to the system was not engaged at maximum throughput.

Phase II and Beyond

While the speed bumps were distressing, they were fortunately not terminal. Most of the problems could be addressed in straightforward and reasonably timely methods. The orphaned SQL connections could be eliminated with programming changes. Certain user actions, such as moving a patient between rooms or querying a patient’s status, not fully tested during performance testing, spawned the majority of these connections. While there were dozens of instances in the SQL stored procedures, as each was identified and updated, incremental improvement was seen across the application.

The primary inbound appointment interface was modified to send only current day appointment updates, and a separate batch interface was created to synchronize the application with the next day’s appointments later in the evening. While the two-pronged interface could only be a temporary fix until a more efficient single interface could be designed, the change resulted in an immediate 30 percent reduction in data traffic throughout critical sections of the application.

Better indexing and a segmentation of static and volatile data produced additional gains. For example, appointments that are cancelled by patients or providers represent a significant number—up to one third—of appointments residing in both the source scheduling system and Patient Tracking, but once cancelled are never touched again. Pending appointments have a much higher activity rate, often being touched multiple times for edits after being scheduled but before the patient arrives. Separating cancelled and pending appointments into separate database tables resulted in approximately a 25 percent reduction in volume on the most highly accessed data.

By the end of October, the performance issues had been overcome, and Patient Tracking was operating as expected throughout the YCOC. Over time, enough new-building issues like electricity, heating, and elevators rose to the forefront, and the application’s rocky start was relegated to footnote status of the building’s history. Later in the year, the team had a short-lived scare when application performance would start to decline periodically during the week, only to recover within an hour or two. After some investigation, the cause was discovered to be a single user whose computer was infected with a virus. When the user logged onto the infected PC, the virus pummeled the tracking application by repeatedly downloading a particular image from the server.

Planning began for Phase II immediately after the team had stabilized Patient Tracking after its bumpy start. In January 2005, the remaining floors of the YCOC would be occupied by an in vitro fertilization clinic and 17 Cancer Center practices, including a 60-bay infusion unit. This would double the number of Patient Tracking users. New functionality would include batch style interfaces from the radiation oncology, radiology/ultrasound, and infusion scheduling systems, which were not configured to support real-time interfaces.

Lessons learned from Phase I were incorporated into the Phase II test plan, and the production system itself provided an accurate set of benchmarks. The only significant infrastructure change made was to upgrade the SQL server from two processors to four, to ensure plenty of computing power for additional users. The Phase II go-live went smoothly, and the application absorbed the increased load with nary a hitch.

Un-measurable Success

The development team is unable to provide Six Sigma-style data-driven results to verify the value of Patient Tracking. The significant change in operational structure and flow between the old space and the new YCOC layouts exceeded their ability to gather data and normalize for comparison. In the future, the rich set of data Patient Tracking is collecting will provide such a baseline for evaluating future patient care workflow enhancements.

While not tangible, user feedback and continued, expanded, and innovative use of the application helps define its value. Practice managers report that communication and operations have improved through use of the application. Physicians, initially not expected to be heavy users of the application, have become quite active. Proactively managing their own schedules, they now know when a patient is ready to be seen and how long they have been waiting, and they can greet the patient appropriately, improving customer service and increasing their own efficiency.

Departments have requested that new indicators and timestamps be added, as Patient Tracking has enabled them to incrementally improve workflow. As an example, the infusion unit recently requested the addition of treatment code indicators to accommodate time-based reporting on
specific treatment regimens, which will eventually enable them to modify clinical practice. While technology will often solve a problem but force a substantial change in process, Patient Tracking has managed to tame a radical new workflow imposed by environmental changes.

In addition to supporting patient flow in the YCOC, the development of the application enabled a cottage industry of additional operational-enhancing systems to sprout. As a byproduct of its design, the application became the first campus-wide appointment repository, capturing accurate data on approximately 95 percent of all outpatient visits, a valuable asset.

The first follow-up application was an appointment locator service for use by MGH Information Ambassadors, who assist patients and visitors in finding their way around the campus. The robust appointment database, coupled with explicit building/floor/suite data exposed by Patient Tracking, enables the Ambassadors to provide vastly increased customer service and add indefinable but real benefit to the efficient flow of the campus.

The second application to come online was for parking and security to use when validating patient parking. Use of the limited parking facilities around the campus for non-visit or non-patient related parking, such as by employees or customers of local businesses, has a definite impact on customer service and efficiency, as patients looking for parking either miss their scheduled time or perhaps seek care with another provider altogether. The Patient Tracking repository provides data for the application to verify a patient visit had occurred, enhancing customer service and efficient operation while maintaining confidentiality.

Currently under development is an air-traffic control style application for the MGH Interpreter Services department. The interpreter services application will use Patient Tracking as a data source to plan daily staffing levels and will eventually support bidirectional communication between practice staff and Interpreter Service staff.

The application will continue to grow and build on the success it has enjoyed. The expansion to MGH clinics beyond the YCOC was recently approved, and there are tentative plans to roll the application out at other Partners’ facilities, and potentially license the technology to other healthcare providers.

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