Medical devices such as patient monitors and ventilators are rich in discrete data, making them a natural fit to integrate with electronic medical record systems (EMR). The Ohio State University’s Wexner Medical Center decided to make an investment during the initial EMR install to purchase a medical device integrator (MDI) to capture this data for permanent storage in the patient chart. Through the patient monitoring solutions that OSUWMC implemented, the organization realized consistency (93% of vitals were captured by a device automatically), timeliness (81% of vitals were validated within one hour), and confidence in patient safety (established foundation for deterioration monitoring). In addition to clinical benefits, OSUWMC also saved time and resources for nursing staff (96 hours of time savings for nursing per week, or 2.4 nurses per year for the 7 nursing units studied).
Background Knowledge
Prior to the electronic medical record (EMR) install October 15, 2011, The Ohio State University’s Wexner Medical Center (OSUWMC) had several niche systems that captured patient vitals and ventilator data, but there was no common methodology and none of the data was shared among different systems. For example, the ED system captured vitals, but if the patient was admitted, the vital sign capture ceased in the ED system and started anew in the ICU system. If the patient was subsequently sent to surgery, the vitals were not captured electronically at all, nor could the surgeon review previous vitals. The most common scenario occurred when the patient was transferred to a step-down medical surgical bed and was accompanied by a 500+ page printout from the ICU system. This printout contained every vital sign in a list format along with other data. The receiving nurse was expected to review this excessively large document to make clinical decisions while transitioning the patient. To make matters worse, only the ICU and ED systems had the capability of integrating device data but the legacy EMR was unable to provide like functionality so the nurse now had to start vital capture on paper.

Local Problem and Intended Improvement
During the EMR install, OSUWMC made the commitment to not go backwards in functionality in keeping vital and ventilator data capture in the ED and ICU areas. Instead, we set a baseline standard across any inpatient area that all bedside patient monitoring and all ventilator data would be captured using a single, consistent method. All data would be stored permanently in the EMR for any clinician to view and trend. The consistent process would set a baseline set of data that could be used for larger “big data” efforts, such as the Modified Early Warning System (MEWS), which can help signal when a patient’s condition is deteriorating.

With the desire to take full advantage of the new EMR installation, we decided to form a cross-functional team to evaluate all devices that could integrate with discrete data. This team consisted of representation from Nursing, Clinical Engineering, HIM, Quality, PACS, Revenue Cycle and IT which started meeting roughly 10 months prior to the EMR enterprise install. One daunting task was to identify what devices were capable to integrate. Nursing units and ancillary departments were polled and visited, clinical engineering preventive maintenance records were searched and charges were pulled to identify potential devices. A total of 45 devices were found which meant the committee would need to evaluate the feasibility of integration. To do this in a methodical manner, a scoring algorithm was developed using the following criteria: Scope, Volume, Visibility and Risk. Each of these 4 criteria had a 1-10 scale with established weights. Given the limited time, the sum of the 4 criteria was multiplied by the ability of the system to produce and send data discretely. A system that could not send data meant a multiplier of 0, negating the score. Other systems had a ranking based off estimates to perform the work resulting in a weighted score with more difficult projects falling with a lower priority than easier
projects. Finally, each device and associated score was grouped into waves that allowed for the appropriate implementation team to be assigned. Ultimately, the waves were simplified into the following:

- **Flowsheet**: Discrete data sent to the EMR and displayed in spreadsheet-like cells
- **PACS**: DICOM-enabled devices that could be added to an existing environment
- **PDF**: Documents that could be imported into a document imaging system

### Score = (Scope + Volume + Visibility + Risk) * Ability

#### Group into ‘waves’ which allowed for appropriate teams and timelines

<table>
<thead>
<tr>
<th>Wave</th>
<th>Flowsheet</th>
<th>PACS</th>
<th>PDF</th>
<th>Wave 1</th>
<th>Wave 2</th>
<th>Wave 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Dept 3</td>
<td>Mult Depts 6</td>
<td>Housewide 10</td>
<td>Size 3</td>
<td>Size 6</td>
<td>Size 10</td>
</tr>
<tr>
<td>Volume</td>
<td>Affects a single dept</td>
<td>Affects multi dept</td>
<td>Common in many depts</td>
<td>Low 3-10 cases/day</td>
<td>Med 10-100 cases/day</td>
<td>High 100+ cases/day</td>
</tr>
<tr>
<td>Visibility</td>
<td>Low 3</td>
<td>Med 6</td>
<td>High 10</td>
<td>Report - No data manipulation</td>
<td>Scan doc line but manual</td>
<td>Scan doc line in multiple locations</td>
</tr>
<tr>
<td>Risk</td>
<td>N/A 0</td>
<td>N/A 0</td>
<td>N/A 0</td>
<td>N/A 0</td>
<td>N/A 0</td>
<td>N/A 0</td>
</tr>
</tbody>
</table>

Once compiled, 5 devices with the highest score became our target list. Topping the list with a perfect score of 400 were patient monitors (house-wide, high volume, required visibility, high risk, somewhat easy to install) followed by ventilators at 360 (similar, but not house-wide), blood gasses at 300, maternal fetal monitoring at 260 and stress nuclear medicine at 160. While there were some that scored higher than the targeted five, they were not in a good state for operational reasons. This included glucose devices, which was in a state of being replaced and dialysis, where the department was being outsourced.

### Design and Implementation

In January 2011, OSUWMC went to bid for a Medical Device Integrator (MDI) that would allow us to capture data from devices that were traditionally difficult to connect to the standard IT network. Several challenges were quickly identified:

**Bio-medical vs. IT Network.** Medical devices are often segregated on a separate network that has no internet and direct user interaction. This is meant to reduce risk of viruses, intrusions,
slowness, etc. Bridging the two networks without compromising patient safety proved to be challenging.

**Clinic Acceptance.** Respiratory therapists are expected to intubate patients quickly in the ICU setting, so the solution could not interrupt or slow their workflow.

**Data Validity.** Ventilator data specifically is difficult to interpret. The data set used while a vent is in one mode is a different data set in a different mode. Respiratory therapists regularly deleted unused or unwanted data elements based off the mode being used, so they needed specific data set based off the mode being used.

To address these challenges, the IT team explored a number of solutions with regards to hardware and streamlined clinical processes. The choices we made, described in the following section, provided a thorough response to these issues and enabled us to accomplish our goals for safety and data capture.

**How Health IT Was Utilized**

A solution was purchased in March 2011 to integrate patient monitors and ventilators when the enterprise-wide EMR was installed in October 2011.

**Patient Monitor Solution.** To bridge the biomedical and IT networks, gateways were purchased that had two network cards, one for each network. This enabled data to be sent from the biomedical network to the MDI application on the IT network. The monitors were polled once per minute and sent real-time to the EMR. This allowed the automated capture of discrete data in a timely and consistent manner.

**Patient Monitor Customizations.** Sending vitals to the EMR every minute was considered a successful measure; however, the solution was taken one step further. Calculations such as the Cerebral Perfusion Pressures were automatically calculated removing a significant time and training effort from nursing. Not only were calculations performed automatically, but they were also performed consistently and correctly.

**Ventilator Solution.** Ventilators offered a special challenge in the fact that they were mobile. In a 1,000+ bed hospital, it wasn’t feasible to hardwire every room with additional network jacks or specialized equipment. Instead, wireless PCs without fans were physically mounted on each of the 137 ventilators and powered by a medical grade power strip also used by the ventilator. The PCs do not have any peripherals, so they are not invasive and unnoticeable. To comply with the respiratory therapy’s direction to avoid any added step in the intubation process, the bios settings on the PC were changed so that the PC booted immediately upon detecting power. By the time the patient was connected to the ventilator, the PC had booted data was already transmitting to the EMR via the wireless web service to the MDI server. The only step the respiratory therapist
did differently was associating the ventilator in the EMR after all patient care steps had been performed, which had data queued to verify.

In addition to capturing data, the respiratory therapy department wanted to avoid an existing issue with every data element being displayed even when not in use. A vent can run in four modes with each mode having a subset of data being captured. This resulted in a long list of variables with many blank or unusable entries. The EMR install took this into consideration and specific flow sheets were developed specific to the mode being captured so only relevant data is captured and displayed.

Patient Safety. From the beginning, clinical engineering was concerned with patient safety and possibilities of electrical shock from ground faults in the medical devices. Unlike standard desktop PCs or even laptops, the fanless PCs were tested to ensure they would run at a safe electrical output to reduce any possibility of shocking. To take patient safety one additional step, an optical isolator was placed between the PC and the device so any ground fault error would be eliminated.

Calculations. Clinical calculations are not always available in the inbound transfer. Data elements can be calculated on-the-fly within the EMR so they are available, consistent and accurate. Cerebral Perfusion Pressure (CPP) is such an example.

Testing. After unit testing was considered successful, three separate integrated tests were performed with complete dedication of several people: A practicing respiratory therapist, a respiratory therapist within the IT department, a nurse in IT with extensive cardiac experience, a nurse from the MDI vendor, 1-2 biomedical engineers and 1-2 technical IT developers. Every data element and calculation and in the case of the ventilators, each data element in each mode was tested extensively.

Value Derived/Outcomes
We performed a value case study in the fall of 2012 to look at the efficacy of this solution, and we presented the results at the 2013 HIMSS conference in New Orleans. This was a randomized, de-identified study that looked at 1 week of data 9-12 months after the EMR go live. The study used an honest broker protocol so exact timeframe was purposely unknown. The data included 7 nursing units: 34 surgical ICUs, 39 medical ICUs and the PACU including 167 unique patients. For simplicity, a single vital value, pulse, was used and resulted in 13,857 unique data points.

Consistency. The MDI solution resulted in 95% of vitals being captured at least once per hour. At least a significant portion of the remaining 5% were due to patients traveling to the OR or procedure areas. Because of the honest broker protocol, it is not possible to determine a further breakdown. Additionally, due to limitations from the previous solution, pre-implementation baseline levels for automatic capture are not available.
In addition, the study found 93% of vitals were captured by a device automatically. The remaining 7% were captured manually.

**Confidence.** Because OSUWMC was able to justify the timeliness and accuracy of the vitals data set, it could be used as a platform to use in the Modified Early Warning Score (MEWS), which was implemented several months after the EMR installation. MEWS is a calculation that is based on hemodynamic data and some subjective data, based on a patient assessment. This score predicts trends and/or a sudden patient de-compensation. With the implementation of MDI, the timeliness and accuracy of the score has had a positive impact on predicting adverse changes in patient condition and consequently implementing interventions in a timely fashion.

**Timeliness.** Validation is extremely important in this process. In the EMR solution, any data that has not been validated is purged from the system after 24 hours. The study found that 81% of vitals were validated within one hour. Another 8% were validated between 1-2 hours. As described above, 7% were entered manually which bypasses the need for a validation process. Only 4% were validated after 2 hours. This naturally raises a question that if the MDI solution was not in place, would this 4% have been captured at all? Is unvalidated data better than no data at all? In 2015, a Sepsis Task Force had determined that unvalidated data was truly better than no data and championed a project to use the unvalidated MEWS scores with any change in temperature, pulse, respiration, and/or blood pressure to alert for potential sepsis patients. Outcomes of this effort will be researched once more data can be obtained.

**Lessons Learned**

The time study resulted in many subjective comments overheard, which were overwhelmingly positive. Nurses really appreciated the ease, completeness and consistency of the process. The MDI solution has proven to be solid and reliable and is now being expanded into anesthesia and other devices.

Following the implementation of the MDI solution, we observed additional areas for future improvement:

**Fanless PCs.** All efforts made to reduce workflow changes for the respiratory therapists were successful by automating the start of the PC and in effect, hiding it from view. However, the hard shutdown when a therapist unplugs the ventilator has caused issues with the underlying Windows operating system. Because of this, one to two PCs each month have operating system failures, requiring a reimage. OSUWMC continues to investigate other PC solutions that would avoid the hard shutdown while continuing to support the seamless workflow currently in place.

**Research.** 15, 20, 60 or 240 minute time intervals for data capture work well for clinical needs. However, these intervals are not sufficient for some research. OSUWMC will soon begin a project to send all 1-minute data intervals to the Data Warehouse for research needs. Additional
business rules will need to be added to filter skewed data, such as when a patient is coughing when the vitals were captured.

**Financial Considerations**

The intent behind the purchase of an MDI solution was patient care and patient safety by means of capturing this data in an automated fashion. A one-time purchase of ~$1,000,000 USD was invested in an enterprise MDI solution along with ~$140,000 in fanless PCs.

OSUWMC did realize an unexpected reduction in labor. It takes roughly 31 seconds to manually complete an average set of vitals. This is higher in the cardiac areas where calculations need to be performed manually. To validate this information, however, takes 6 seconds, resulting in an 81% decrease in time for data capture. Assuming 1 set of vitals per hour for the 167 patients just in the ICUs and PACU areas, this results in an estimated 96 hours of time savings for nursing per week or 2.4 nurses per year for the 7 nursing units studied. This number increases if vitals are taken multiple times an hour, which is common in high acuity areas. This is time nursing staff can spend doing other clinical functions.

Because OSUWMC invested in an enterprise MDI solution, a minimal investment in hardware and implementation fees was made to expand the solution into anesthesia 28 months after the original EMR installation. A total of 78 anesthesia machines, which includes integration from over 200 individual devices, are integrated real-time during operations. In total, the number of devices integrated with the EMR has over doubled in four years post the enterprise EMR install with a clear upwards trajectory although this is admittedly due to both integration efforts as well as growth. OSUWMC however has committed to a team of three dedicated full time employees as well as help from Clinical Engineering, IT and Nursing to maintain and continue to grow this effort.
Number of integrated devices by type