ED Administration

Applying the Lean principles of the Toyota Production System to reduce wait times in the emergency department

David Ng, MD; Gord Vail, MD, MSc; Sophia Thomas, MD; Nicki Schmidt, RN

ABSTRACT

Objective: In recognition of patient wait times, and deteriorating patient and staff satisfaction, we set out to improve these measures in our emergency department (ED) without adding any new funding or beds.

Methods: In 2005 all staff in the ED at Hôtel-Dieu Grace Hospital began a transformation, employing Toyota Lean manufacturing principles to improve ED wait times and quality of care. Lean techniques such as value-stream mapping, just-in-time delivery techniques, workplace organization, reduction of systemic wastes, use of the worker as the source of quality improvement and ongoing refinement of our process steps formed the basis of our project.

Results: Our ED has achieved major improvements in departmental flow without adding any additional ED or inpatient beds. The mean registration to physician time has decreased from 111 minutes to 78 minutes. The number of patients who left without being seen has decreased from 7.1% to 4.3%. The length of stay (LOS) for discharged patients has decreased from a mean of 3.6 to 2.8 hours, with the largest decrease seen in our patients triaged at levels 4 or 5 using the Canadian Emergency Department Triage and Acuity Scale. We noted an improvement in ED patient satisfaction scores following the implementation of Lean principles.

Conclusion: Lean manufacturing principles can improve the flow of patients through the ED, resulting in greater patient satisfaction along with reduced time spent by the patient in the ED.

Keywords: ED administration, Lean principles, length of stay, time to physician, wait time

INTRODUCTION

Emergency department (ED) wait times have become a focus for the Canadian public, the media and the government. Factors external to the ED, such as improving access to inpatient beds, developing overcapacity protocols, adding clinical decision units and reorganizing
ambulance services have been proposed to improve ED patient flow.\(^1\)\(^,\)\(^2\) We have found few published reports that discuss improving internal ED efficiency to reduce wait times. Similar to most hospitals in Ontario, ED overcrowding and ambulance offload delay have been worsening at our site, due in part to a lack of available inpatient beds.\(^3\)\(^,\)\(^4\) Our ED had previously attempted various solutions to improve wait times and attain recommended Canadian Emergency Department Triage and Acuity Scale (CTAS) wait time targets. Specifically, we increased the number of triage nurses and stations, added medical directives, increased physician staffing, hired a nurse practitioner and opened a fast track area. Despite these efforts there was little appreciable impact on overall ED wait times. In September 2005 our ED embarked on a makeover of our departmental processes, based on Lean manufacturing principles that were developed at the Toyota Motor Corporation.\(^4\)

Lean techniques are widely used throughout the manufacturing industry to provide just-in-time delivery of product and ultimately to create value for the consumer using the least resources. These techniques have particular relevance to the current medical system in Canada, where the demand is outpacing capacity to provide care in a timely manner. Lean techniques have been adopted in some hospitals.\(^5\)\(^,\)\(^6\) The product manufactured in the ED can be considered timely, accurate and empathetic medical care. “Lean” is a term related to philosophies derived from the Toyota Production System. The main goals of the Lean system are to create standardized work in order to smooth out the workflow and to eliminate wasteful steps in a process. The Lean system concentrates on attaining continuous flow through a system by identifying value in each step of a process. If a step fails to add value or results in a redundancy to the next user in the process, it impedes quality and flow, and is eliminated (Box 1). By further reducing wait times between steps, and providing exactly what the next user in the process requires, quality and productivity improve.

Lean thinking emphasizes identifying the root cause of a delay or problem by going to the worker and workplace to understand the demands of the work. Front-line workers are taught to identify waste, and to improve and standardize their step in the process.\(^7\)

Although many causes of ED overcrowding are a result of factors beyond the direct control of the ED, such as hospital inpatient capacity, there are factors within the scope of the department that could be changed to improve efficiency and patient satisfaction. The scope of our project involved improving the intradepartmental flow of patients discharged from a tertiary ED in Ontario. In our ED, approximately 85% of patients are treated and discharged. By applying Lean techniques to the population of dischargeable patients, we hypothesized we would improve ED efficiency and productivity, and ultimately reduce ED wait times and improve patient satisfaction.

METHODS

Setting and design

We performed a before and after study. The ED of the Hôtel-Dieu Grace Hospital, in Windsor, Ont., is a regional trauma, cardiac, neurosciences, renal and psychiatric referral centre serving a population of 450 000. The annual census of the ED is approximately 55 000 visits.

Intervention

The project began with a scoping exercise that was facilitated by a Lean consultant, Dr. John Long, to determine the parameters, participants and goals. Those participating were emergency physicians; nurses; nurse practitioners; porters; clerks; cleaning staff; administrators; the ED director, unit manager and educator; the hospital’s senior vice-president; and representatives from diagnostic imaging, laboratory, respiratory therapy, home care and information services. All agreed that the focus would be CTAS-2 to -5 patients deemed at initial triage to be “dischargeable,” as opposed to

<table>
<thead>
<tr>
<th>Box 1. The 7 sources of waste, with selected examples relevant to the emergency department</th>
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<tbody>
<tr>
<td>• Overproduction: creating more work than is required by the next step (e.g., over-triaging)</td>
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<td>• Motion: extra steps for the worker or moving machinery around (e.g., “Where’s the IV pole?”)</td>
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<td>• Waiting: time spent waiting for the next step in the process to occur (e.g., waiting for available bed, consultant, lab and diagnostic imaging results)</td>
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<td>• Conveyance: moving materials around (e.g., lab results on paper)</td>
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<td>• Processing: non-value added work steps (e.g., shuffling patients and stretchers to accommodate new arrivals)</td>
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<tr>
<td>• Inventory: excessive stockpiling of materials (e.g., 1000 tongue depressors in a drawer and no gel)</td>
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<tr>
<td>• Correction: reworking or scrapping work that has already been done (e.g., triage nurse reassessing patients in waiting room)</td>
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IV = Intravenous.
“admit” or “uncertain.” We excluded patients presenting to the ED with primarily psychiatric complaints.

The group convened for a value-stream mapping kaizen workshop over 3 consecutive days in September 2005. The first day focused on creating a current-state map for dischargeable patients. The second day devised the future-state map of the ideal ED process. The last day outlined the improvement projects that would lead toward this ideal.

The current-state value-stream mapping exercise (Appendix 1, available at www.cjem-online.ca/v12/n1/p50) created a view of the actual process steps involved in patient care for dischargeable patients. As a group, we placed each sequential step of work, from registration to postdischarge, on the current-state map. For each process step, we identified the suppliers (i.e., those who supply the work) and customers (i.e., those who receive the work). For each step, we estimated based on experience the process time, the prestep queue time (i.e., the wait time) and the frequency for which that step was both complete and accurate. We also mapped information flows, such as laboratory, diagnostic imaging and consultations. The group identified rework as occurring when process steps were repeated because of a change of information, or incomplete or inaccurate prior steps. We drew arrows on the map to connect the points of rework, forming rework loops.

Once the current-state map was drawn out, it was possible to visualize the complexity of processing a patient through the ED. We summed the process times and wait times to determine the total lead time. At this point, with all the steps mapped out, we asked participants to identify 3 key bottlenecks in the entire value stream from registration to postdischarge. At the end of day 1, the group presented the current-state map and metrics to a decision panel, which included senior administrators and physicians within the hospital. The group answered questions, accepted criticisms and obtained approval to proceed to the future-state map.

Day 2 of the workshop involved the creation of the future-state value-stream map (Appendix 2, available at www.cjem-online.ca/v12/n1/p50). We reviewed the current-state map, and grouped sequential steps into components of care, creating “chunks.” We either eliminated or combined repetitive process and work steps within each chunk. Between each chunk, we identified suppliers and customers, as well as inputs and outputs.

To ensure the process steps within a chunk proceeded seamlessly, we established standard agreement on what inputs were required to begin each step, and what outputs were required at the end of each step. We identified the necessary changes required to meet the demands of the customer at each chunk as standard work. Finally, the group agreed on and set as the ideal target the expected length of time to complete each chunk (i.e., lead time). We then presented these results to the decision panel at the end of the day.

The final day of the workshop was the project planning phase. Projects were created around the “sort,” “discharge” and “postdischarge” chunks of the future-state map. We established 3 general priorities: workplace organization to improve the layout of the ED, creation of standard work that every worker was expected to do consistently and communication of Lean concepts and projects to the ED staff. We assigned project leaders, timelines, objectives and outcome measures to each project. We then presented the projects and implementation plans to the decision board for approval.

To illustrate, an initial key project involved sorting patients into admitted or dischargeable streams, based on the assumption that triage nurses could predict which patients would be discharged from the ED. Triage nurses were asked to assign the category of “discharge,” “admit” or “uncertain” to each patient (Table 1). We excluded patients who arrived by ambulance, had primarily psychiatric complaints or were deemed CTAS-1 (emergent). We measured the accuracy of this decision during the day shift over 11 days. In March 2006, another project involved the reorganization of our ED into a probable admission area, a dischargeable area and a complex dischargeable area (i.e., for those uncertain patients requiring lengthier testing and care within the ED; e.g., renal colic, abdominal pain, atypical chest pain and asthma). All of these areas were located within our ED and represented, simply, a label attached to groups of existing beds.

To implement and sustain the projects, the ED leadership team created a Lean education and project board, organized staff information sessions, recruited front-line staff to be project team leaders and met weekly to review metrics. A full-group kaizen project

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<th>Table 1. Accuracy of triage nurse to predict discharge</th>
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<td>Prediction at triage</td>
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<td>Predicted discharge</td>
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<td>Uncertain</td>
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<td>Predicted admission</td>
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review took place every 2 to 3 months. New projects were created based on staff suggestion and input, and were implemented on “suck-it-up Wednesdays.” On this day new projects were trialed, and the ED staff was required to try the change and then provide feedback directly to team leaders, the Lean facilitator or the information graffiti boards.

**Outcome metrics**

Because of the lack of an electronic information system in our ED, all departmental metrics were manually compiled through the hospital health records department, and were posted on our communication board on a monthly basis. These metrics included the following:

- mean time to see a physician, defined as time from registration to documented time of physician encounter for all patients (i.e., door to doctor time)
- mean length of stay (LOS), defined as time of registration to the time that the patient physically left the department, for dischargeable patients
- mean LOS for all ED patients, including admitted patients
- proportion of patients who left without seeing a physician, defined as patients who left the ED before physician contact
- overall patient satisfaction score (based on the NRC Picker survey)
- overall ED volumes
- number of admitted inpatients in the ED at 6:00 am

**RESULTS**

We identified 19 process steps involving care of the dischargeable patient on the current-state value-stream map. The total process time ranged from 24 minutes to 19 hours, and the total wait time ranged from 37 minutes to 57 hours, for a total lead time of 61 minutes to 76 hours. When we multiplied the percentages of completeness and accuracy for each sequential step, we estimated only 2% of patients to have received flawless care through our system. Approximately 40% of patients had to repeat steps within the ED current-state value stream (total rework loops).

We organized the future-state map into 6 essential components or chunks. We estimated the total lead time on the future-state value-stream map to be 215 minutes, and we estimated this to be complete and accurate in 84% of cases.

The triage nurses correctly predicted which patients would be discharged with a sensitivity of 86% (true discharges/total discharges = 650/758) (Table 1). Approximately 1 in 7 patients (110/820) was deemed “uncertain” at triage.

From April 2005 to September 2005, the mean wait time to see a physician was 111 minutes. The mean LOS for the discharged patient was 3.6 hours, and 7.1% of patients left the ED without being seen. Following the Lean workshop in September 2005, the mean wait time to see the physician decreased (Fig. 1). From October 2005 to March 2006, the mean wait time was 89 minutes. The mean LOS for discharged patients was 3.3 hours, and 5.0% of patients left without being seen. For the subsequent fiscal year between April 2006 and March 2007, the mean wait time to see a physician was 78 minutes. The mean LOS for discharged patients was 2.8 hours, and 4.3% of patients left without being seen (Fig. 2). The volume of patients seen in the ED remained stable throughout, but there was a substantial increase in ED crowding as measured by the boarding of admitted patients (Fig. 3). The mean number of admitted patients waiting for beds at 6:00 am daily was 1.3 in 2004, 1.8 in 2005, 4.1 in 2006 and 6.1 between January and March 2007.

The reductions in mean LOS were largely confined to patients triaged as CTAS-4 or -5. From April 2004 to March 2005, the mean LOS for CTAS-1, -2 and -3 patients was 4.7 hours; for CTAS-4 and -5 patients, the mean LOS was 3.1 hours. From April 2005 to March 2006, the mean LOS for CTAS-1, -2 and -3 patients...
was 5.0 hours; for CTAS-4 and -5 patients, the mean LOS was 3.0 hours. From April 2006 to March 2007, the mean LOS for CTAS-1, -2 and -3 patients was 4.6 hours; for CTAS-4 and -5 patients, the mean LOS was 2.3 hours.

Finally, patient satisfaction scores improved slightly and became more consistent after the intervention. From April 2004 to March 2005, the mean monthly score was 79.8%, and met the provincial benchmark of 85% for 5 of the 12 months. From April 2005 to March 2006, the overall annual mean was 82.0%, and met the benchmark for 3 of the 12 months. From April 2006 to March 2007, the overall annual mean was 83.1% and met the benchmark for 6 of the 12 months (Table 2).

**DISCUSSION**

The causes of ED congestion are multifactorial, with hospital overcrowding and increasing ED demand as examples cited in the literature.\(^2,3,8\) Attempts to modify ED inputs, throughput and outputs to improve patient flow have been reported by others.\(^1,8,9\) We were able to find only a few published examples of applying industrial management techniques to improving hospital and ED flow, and these studies do not quantify sustained results.\(^3,10,11\) We report our experience in applying philosophies and tools from the Toyota Production System (Lean thinking) to improve productivity in our ED and to reduce wait times. For this project we focused on ED patients deemed by a triage nurse at presentation to be dischargeable. By reducing wasted steps and better coordinating the medical care for these patients, we hoped to improve the productivity of the ED. We prioritized organization of the workplace layout and standardization of the work, and established continuous communication of Lean concepts to the department.

While discussing and creating the value-stream maps, the group was able to see how inefficiently the ED operated. Previous efforts to improve access involved increasing ED processing at the point of triage. For example, medical directives for blood tests and full nursing assessments were implemented at triage because of an inability to bring patients into an overcrowded department. These directives often resulted in unnecessary or incomplete testing (Lean waste). Delays at triage were exacerbated by the need to reassess patients with extended waits in the waiting room (an example of rework). A single charge nurse was also responsible for responding to calls from the emergency

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<th>Table 2. Overall patient satisfaction scores</th>
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medical service, delivering printed laboratory results to
the paper charts and escorting nonambulance patients
into the ED. The lack of an ED information system and
a central visual signal made it difficult to identify empty
beds in the department. By directing patients to the
next available bed, a nurse could be asked to care for
patients of varying complexity, delaying the care of the
patients requiring less intensive care. Nurses wasted
time looking for equipment that was misplaced, in dis-
repair, inappropriately stocked or in the wrong location.
Often-used materials such as intravenous (IV) solutions
and opioids were stored in central locations to ease the
work for the hospital supply staff and pharmacy, but not
for the main users of the material, namely the nurses.
Porters escorted ambulatory patients to the diagnostic
imaging department in batches, adding to patient wait
times. There were no visual signals on the chart to indi-
cate when investigations were complete. Physicians
wasted time searching for charts, laboratory results and
hospital records, causing unnecessary delay and frustra-
tion. On discharge, patients could linger in their beds
for up to 45 minutes waiting for a nurse to deliver a
prescription, to remove an IV lock, find a wheelchair or
organize transport home. The entire flow of work
within the ED was uneven, and lurched from those
waiting for things to be done to those having too many
tasks to do. The chaos precluded staff finding time to
institute workplace improvements. The value-stream
mapping exercise revealed much waste of effort and
material in our ED.

The value stream exercise allowed a series of bottle-
neck reduction projects to be identified concurrently.
Workplace organization projects had an immediate
impact on efficiency. The front-line staff was asked to
reconfigure these areas with the appropriate stock and
ergonomics. Projects included stocking all physician-
required material to the patient’s right, reorganizing
stock carts such that 90% of the most used stock were
within steps of the patient, negotiating with stores and
pharmacy to deliver stock to required areas in the
required amounts, reducing stocking to maximum and
minimum control levels (such as in a supermarket), foot-
printing or marking the ED floor with designated loca-
tions for necessary equipment to be placed after use
(such as the previously wandering ECG machine). The
entire department was reconfigured so that all dis-
chargeable patients were seen in one area. All patients in
the department were classified as “admitted,” “uncer-
tain” or “dischargeable” on presenting to the ED, and
their charts would be placed in these respective boxes.

Incorrectly assigned patients could be reassigned at any
time during their visit to the appropriate value streams.
The nurses assigned to the dischargeable area were
responsible for filling their own beds based on the visual
cue of the charts in the inbox. This signal was akin to the
Kanban box, which is used to signal work in a Toyota fac-
tory, allowing the worker to “pull” their work at a steady
pace. Having a predictable workload created steady flow
through the ED with an aim toward “just-in-time”
delivery of care. Furthermore, a great emphasis was
placed on reducing the time that a discharged patient
stayed in a bed or chair. Nurses were encouraged to
complete discharge procedures on patients before
receiving the next patient or ambulance stretcher.
Patients requiring home care were identified at triage
and not on discharge. Physicians were encouraged to
provide complete prescription and discharge instructions
to the patient and pull IV locks in order to minimize
delay of bed turnover. A discharged patient order box
and a wheelchair availability project helped to reduce the
time a discharged patient occupied an ED bed. Re-rout-
ing of laboratory results to the printer for the appro-
riate stream improved information flow. Ambulatory
patients were encouraged to self-porter to diagnostic
imaging, thereby freeing up porters for other work.

Improving efficiency for the dischargeable stream had
a positive benefit for the rest of the ED. By increasing
the throughput of patients through a limited but preal-
located number of ED beds, remaining beds were freed
for ambulance offload and boarding admitted patients.
Physicians were also able to attend to higher acuity
patients sooner. Workplace organization projects, such
as streamlining stockrooms and standardizing IV carts
did universal benefit in the ED. Placing dischargeable
patients in a geographically distinct area of the ED
opened other beds in the department for higher acuity
patients likely to need admission. Furthermore, the
improvement in ED patient turnaround time dramati-
cally reduced the number of patients who left without
being seen. Finally, as a result of improving ED process
and wait times, there has been steady and progressive
improvement in our NRC Picker scores for overall
patient satisfaction since September 2005.

A major paradigm shift was required to think of
patient flow in terms of work involved rather than diag-
nosis. By standardizing work based on worker consen-
sus, medical error and miscommunication could be
reduced while increasing the acceptance and sustain-
ability of the change. The challenge of the Lean system
is to train the workers to identify waste and to think in

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and paying for staff to participate in Lean consultant, developing in-house Lean expertise and senior hospital management. There is cost to hiring projects, which requires leadership and support from ED tem involves creating and sustaining the ongoing pro-

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techers has added to the overcrowding and LOS for teaching unit in the hospital for internal medicine

2006 addition of a chasoned over the past year, and we continue to face new challenges. For example, the numbers of walk-in and ambulance arrivals, and admitted patients boarding in our ED continue to increase. The 2006 addition of a teaching unit in the hospital for internal medicine residents has added to the overcrowding and LOS for boarding patients admitted to the internal medicine service, because of a change in how patients are seen and admitted by the teaching service. The fact that our improvements in flow and satisfaction have occurred in the face of these overcrowding pressures is noteworthy.

The greatest challenge in implementing the Lean system involves creating and sustaining the ongoing projects, which requires leadership and support from ED and senior hospital management. There is cost to hiring a Lean consultant, developing in-house Lean expertise and paying for staff to participate in kaizen workshops. Individual projects are often done during clinical hours by front-line staff.

Increased ED efficiency also requires concomitant downstream improvement in information flow from laboratory, diagnostic imaging and physician consultation services. Hospital overcrowding is an issue beyond the scope of the ED and requires a more comprehensive hospital-wide strategy to improve patient flow. Based on the initial success of introducing the Lean system to our ED, our hospital has now created Lean projects in radiology, internal medicine, mental health and orthopedics.

CONCLUSION

We have applied Lean manufacturing techniques to improve the flow within our ED. We concentrated on the dischargeable patient group, which represents the majority of our patients. By eliminating waste from our internal ED processes, improving workplace organization, focusing on reducing interruptions and internal waits, and continuously refining improvements, wait times, length of stay and patient satisfaction have all improved during a period of increased ED overcrowding with no additional staff or beds. The Lean system provides an approach to analyzing process flow and improving efficiency by focusing on the ideas of front-line workers and providing maximum value to the customer. These principles represent a change in how we think about problems rather than a prescription for how to solve problems.

Acknowledgement: This paper is dedicated to our friend and sensei Dr. John Long (1943–2006).

Competing interests: None declared.

REFERENCES


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Current State Value Stream Map - ED Department

Metrics

P/T: Processing Time
Inbox: Inbox Time
W/T: Wait Time
% C & A: % Complete and Accurate

Mapping Icons

- Process Step
- Wait Time
- In Box (Queue)
- Outside Sources
- Information
- Data Box

Decision to Discharge
Prepare Output
Discussion with patient
Discharge patient
Prepare room and test
Prepare output
Follow-up call backs

Referral (Ortho, Plastics)
Transport (EMS, Pts)
Family, CCAC, Others, Crisis (Detox)

Housekeeping, Infection control

Grasp

Process Time
Inbox Time
Wait Time
% Complete and Accurate
Future State Map - Emergency Department

CHUNK 1: Sort

- Ready room
- Greet
- Register
- Sort by RN
- Place direct
- Decide if patient will be discharged

Customer: ERP
Demands:
1. Rt. Pt. in rt. place
2. Rt. info.
3. Rt. equipment
4. Rt. order to be seen

LEAD TIME: 10 min
% C & A: 100%

CHUNK 2: Assess and Order Tests

- ED evaluation
- Order treatment
- Order tests
- Start treatment
- Input orders
- Draw blood
- Porter

Customer: Info.
Services
Demands:
1. No add-ons
2. C & A inputs
3. Timely
5. Clinical info.

LEAD TIME: 30 min
% C & A: 95%

Changes/Tools:
1. Change layout
2. Standard work
3. Mobile registration
4. Early D/C planning

Changes/Tools:
1. Faster order entry
2. Standard work
3. Manage interruptions
4. Improve portering
Future State Map - Emergency Department

CHUNK 3: Decision

- Information Results
- Receive results
- Interpreted results
- Order treatment
- Perform treatment

Customer-ERP Demands:
1. Results C & A
2. Timely
3. Treatment completed

Lead Time: 90 min.
% C & A: 95%

Changes/Tools:
1. No consults in D/C home group done in ED
2. Consultation standards
3. Investigation standards

CHUNK 4: Discharge

- Information
- Review
- Diagnosis
- Prepare Output
- Discuss with pt.
- Discharge pt.

Customer-Patient Demands:
1. Dx accurate
2. Symptom relief & mgmt.
3. Follow-up care
4. Health teaching/education

Lead Time: 15 min.
% C & A: 98%

Changes/Tools:
1. D/C instructions refined
2. Improved access to interpreters
3. Better access to equipment
Future State Map - Emergency Department

CHUNK 5: Post Discharge

Complete Output
Break down chart closing
Ready Room

Customer - Health Records
Demands:
1. C & A
2. Legible
3. Timely

Lead Time: 10 min
% C & A: 100%

Changes/Tools:
1. User friendly GRASP
2. Standard work

CHUNK 6: Call backs

Customer - Patient
Demands:
1. C & A
2. Timely follow-up

Lead Time: 60 min.
% C & A: 95%

Changes/Tools:
1. NIGHT MD review reports
2. Decrease # of copies of results
3. Standard work