CAN A CLINICAL DECISION SUPPORT TOOL INCREASE ADHERENCE TO A PRACTICE GUIDELINE IN CHILDREN PRESENTING TO THE EMERGENCY DEPARTMENT WITH A MINOR HEAD INJURY?

by

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CERTIFICATE OF APPROVAL

This is to certify that the Master's Capstone Project of

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Can a Clinical Decision Support Tool Increase Adherence to a Practice Guideline in Children Presenting to the Emergency Department with a Minor Head Injury?

Has been approved

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Abstract

BACKGROUND: Investigators sought to determine whether or not integrating a clinical practice guideline into an electronic record (EHR) would improve adherence in pediatric patients presenting to the emergency department for minor head injury.
METHODS: Twenty-seven clinicians working in a tertiary pediatric emergency department were enrolled. Clinical alerts were set to fire according to select chief complaints that could be related to head injury. A head injury navigator (HIN) was devised for clinicians to utilize and determine a risk score of serious intracranial injury (c-TBI). The pre-intervention phase included questions but no risk score revealed while the post intervention phase revealed the risk score to the clinician in real time. The primary outcome was the change in adherence to the guideline post intervention.
ANALYSIS: A Welch t-test was used to compare descriptive variables pre and post intervention. The primary outcome of 'adhered' was compared between the pre and post intervention groups using a marginal logistic regression model.
RESULTS: The HIN was completed 674 times. 31 patients were excluded leaving 641 patient visits. 328 patients (81%) had a positive adherence rate to the guideline pre-intervention as opposed to 203 (86%) post intervention. Estimated OR of the post intervention group divided by the pre intervention group was 1.345 95%CI (0.987-1.835). The number of CT imaging studies pre intervention was 70 (17%) vs. 36 (15%) p = 0.321
CONCLUSION: No statistical difference was seen in pre vs. post intervention group in adherence rates or rate of CT imaging.

Introduction

Head trauma is a common complaint in the emergency department (ED), and imaging is frequently used to assess intracranial damage. It has been estimated that 50% of children being assessed for head injury get a computed tomography (CT) scan. Although rapid identification of the need for medical or surgical intervention is vital, many children who present with minor head injuries are at lower risk for clinically significant brain injury (c-TBI) and may safely be treated with careful observation rather than radiation. Scoring systems have been developed that can identify this group of patients[1].

There is wide variation in CT utilization in head injury. The outcome in emergency settings is clinically important, and the decision rule often can be clearly defined. For example whether or not a patient requires imaging. Also, there are an increasing number of studies concentrating on the development of a clinical decision rule[2].

There is a large degree of practice variation amongst clinicians when evaluating children with head injury in the emergency department. Substantial ED resources are consumed. In a study of adults and children, Bazarian and colleagues found that 44% of patients had CT scans to evaluate head injury, but 38% were discharged without specific follow-up. In documented head injuries, 43.8% of patients did not have this issue addressed[3].

Because many hospitals are implementing electronic health records (EHR), clinical decision support (CDS) may improve the delivery of care. Shifman and colleagues have demonstrated better adherence to guidelines using computer based guideline implementation systems[4].

Setting

A tertiary children's hospital, Rady Children's Hospital Emergency Department has 75,000 visits annually. The hospital is a level one trauma center and has a large catchment area. It is the only children's hospital and trauma center in San Diego County. It is a university hospital with a high number of children presenting with head injuries.

Stakeholders

The following is a list of stakeholders for this project.

- Chief Medical Information Officer provided institutional support for the project, facilitate project approval, and organize analysts.
- Advisor from Oregon Health & Science University (OHSU) had continual oversight of the project, making any appropriate suggestions during the project implementation.
- Pediatric Emergency Medicine staff (physicians, residents, fellows, nurse practitioners,) were the end users making the clinical decisions or intimately involved in patient care.
- Certified Epic Informaticist helped build the templates that calculated the risk assessment. Also, data analysts to run reports.

- Parents, patients, and the community at large benefit if fewer children are exposed to radiation and are potentially healthier later in life, posing less of a future economic burden.

Literature Review

Head Trauma Studies

In a large clinical trial, Kuppermann and the PECARN group developed decision rules to predict which children were at very low risk for c-TBI following a minor head injury[5]. The decision rule was derived from clinical predictors among 8,502 children and validated among 2,216 children. Two decision rules were derived based on age (see Figure 1). Use of this rule, because of its high sensitivity, could have eliminated 25% of CT scans in this study. (Fig 1)

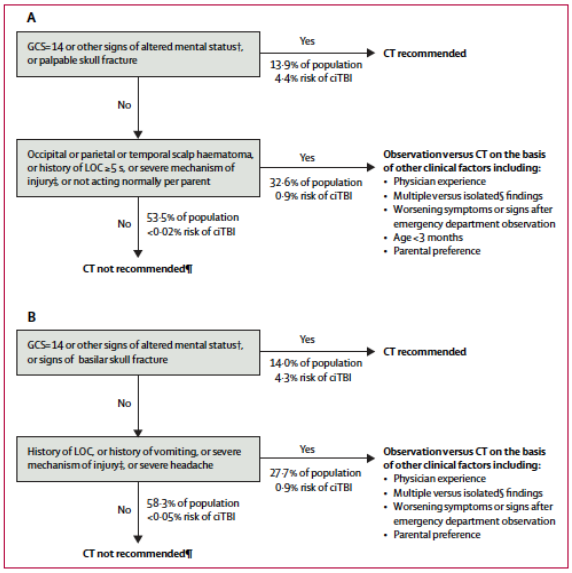

Figure 3: Suggested CT algorithm for children younger than 2 years (A) and for those aged 2 years and older (B) with GCS scores of 14–15 after head trauma*

Figure 1 PECARN decision rules

Nigrovic, working within the PECARN group, followed a prospective cohort of children with minor head injury presenting to the emergency department for evalaution[6]. After patients were evaluated for minor head injury, clinicians were asked prospectively whether they chose to obtain CT scans immediately or observe patients prior to deciding on imaging. The charts were reviewed retrospectively and the children were put into one of two groups. One group was for those who were observed and the other for those who received CT rather than observation. The rates of CT scan imaging were compared between to the two groups. Children in the observation group had a lower CT rate than those in the non-observation group. The rate of intracranial injury was similar in both groups. This study was important because it supports the idea that, under certain conditions, observation can be as valuable as imaging.

Another approach to the assessment of head injury and the development of a clinical decision rule, the Canadian Assessment of Tomography for Childhood Head Injury or CATCH rule, was developed by Osmond[7]. This study took place at ten Canadian teaching hospitals. Patients were enrolled if they had blunt trauma to the head with witnessed loss of consciousness (LOC), amnesia to the event, repeated vomiting, Glasgow Coma Scale (GCS) of 13 or greater, and injury in the past 24 hours. The variables most highly correlated with brain injury were suspected open or depressed skull fracture, large boggy hematoma of the scalp, and low or deteriorating GCS.

LOC has also been studied by Dunning and incorporated in derivation of another rule, the Children's Head Injury Algorithm for the Identification of Significant Clinical Events (CHALICE) rule[8]. In this study, LOC for longer than five minutes had a positive predictive value (PPV) of 0.45. In addition, amnesia for longer than five minutes had a 0.22 PPV. Vomiting more than three times was less predictive, with a PPV of only 0.065.

Palchak and colleagues studied whether or not the length of time of LOC was a predictor of c-TBI[9]. They prospectively enrolled children with blunt head trauma and found no difference in the predictive value of LOC or amnesia relative to c-TBI.

Radiation Exposure

The rate of CT use in children with head injuries has increased greatly in recent years; one estimate suggests a 23% increase from 2000 to 2006[10]. Development of helical CT has made imaging faster and has made dynamic imaging possible, further increasing its use[11].

CT utilizes ionizing radiation, increasing the risk of cancer later in life. This risk is amplified in children for several reasons. Because cancer develops over time, children have a longer period of time to express cancer resulting from radiation exposure in childhood. Children also have more dividing cells than adults. Radiation acts on dividing cells, so children are more sensitive to its effects[12,13].

Although CT exposure can be reduced for a child's lower weight, in practice it is not typically adjusted. This results in a dose that is higher than it would be in a heavier adult. This risk amplification is a non-linear relationship; the risk increases sharply as age at CT decreases[11].

Head CT can lead primarily to development of brain or thyroid cancer later in life, although it has also been associated with leukemia and cancer of the digestive tract, lung, and breast[11]. The estimated lifetime cancer mortality risk following a head CT at one year old is one in 1500. Based on current CT usage, an estimated 2.7 million children undergo CT each year in the United States, and approximately 500 children will later die from cancer resulting from CT scans done in one year[11,12]. Including non-fatal cancers in these estimations would increase these numbers.

One of the most effective ways to reduce exposure is through increased awareness of long-term danger of radiation. Awareness varies by profession; one survey reported that only 9% of emergency-department physicians were aware that CT exposure increases the risk of cancer, yet 47% of radiologists were aware of this[14].

Risk of anesthesia

At healthcare facilities such as Rady Children's Hospital San Diego Emergency Department, propofol is used. Propofol is a rapid acting hypnosedative drug, a commonly used anesthesia for pediatric patients. Many providers use propofol to sedate children, due to its effectiveness in imaging studies, and a shorter recovery time than pentobarbital. It does not pose a higher risk of adverse events than other techniques, and has a favorable pharmacologic profile - having rapid onset and offset, and easy titration[15].

Intravenous propofol administration must be conducted under direct supervision of a qualified physician with experience in airway management and cardiorespiratory pathophysiology of infants and children. Propofol is considered deep sedation, requiring continuous monitoring of the patient's physiologic functions to observe and react to adverse events, and the potential need for general anesthesia during procedures[16].

Performing deep sedation of children requires more resources than in adults[16]. Medical history and physical examination of the child need to be taken into consideration[17]. The incidence of adverse events during imaging sedation/anesthesia varies according to the sedation/anesthesia technique used, the type of clinician administering in different settings, and patient demographics being sedated[15]. A child under sedation, despite related risks, should provide high quality diagnostic images[17.]

Anesthesia adverse events

Although low, there are still risks involved with procedural sedation[18]. An eight-year study at the National Institutes of Health (NIH) Clinical Center defined adverse anesthetic events as sedation procedures with occurrences needing intervention. The NIH data revealed that adverse events occurred when anesthesia commenced (35%), during maintenance (30%), emergence from anesthesia (23%), and during recovery from anesthesia (7%). There was at least one adverse event in 534 per 10,000 anesthetic procedures in this study. Other studies reported an overall incidence of complications of 592 per 10,000 anesthetic procedures[15]. No long lasting morbidity, mortality, or cardiopulmonary resuscitation occurred.

Sedating children incurs more risk when compared with the adult population. The risk is amplified with deeper sedation[16]. While under propofol, a child may move through the states of moderate sedation, deep sedation, and general anesthesia quite easily[15]. Propofol can also be associated with serious side effects. It should be used with caution in children who do not have American Society of Anesthesiologists class I or II and those with multiple-system or metabolic diseases[19]. The anxiolytic effects of propofol and relative intravascular volume depletion due to prolonged fasting were found to contribute to transient episodes of hypotension. Higher doses may also cause increased occurrences of hypotension and respiratory depression. These incidents, however, were found to be mild[19].

Another study found that anesthesia risk may be tempered by the organization's ability to manage adverse events, provide adequate training, and promote safe use of the drug[20].

Although not preventable, the adverse risks in using sedatives/anesthesia are real, known, expected, and manageable[15.]

Clinical Decision Support

Clinical decision support systems (CDSS) have been shown to make improvements in care effectiveness by increasing adherence to evidence-based care guidelines shown to positively impact patient care quality.[21] CDSS may improve effectiveness in the high-risk, busy ED environment by assisting clinicians to increase the utilization of best-practice rules and reduce excessive use of diagnostic testing that does not improve outcomes at the point of care[22].

Similar to head injury, clinical decision support reduced overuse of CT scans for diagnosis of pulmonary embolism (PE) in the ED. When the provider ordered a CT scan using electronic order entry, there were two required fields for D-dimer result and level of clinical suspicion for PE. If the patient was low or intermediate risk, decision support was given to order a D-dimer as an initial step, and if normal, the recommendation was that diagnosis of PE with a CT scan was unlikely. The provider could still bypass the recommendation based on clinical judgment. In the two years following the intervention, CT scans decreased by 20.1% and had an increase yield of a positive result for PE of the ordered scans to 69.0%. In planning the implementation of the intervention, evidence for the recommendations were communicated to ED physicians at various meetings possibly influencing the successful adoption of the CDSS recommendations and the resultant reduction CT scan overuse[23].

Though there was a range in success of the CDSS to improve quality in the realm of effectiveness of care in the ED setting, most of the studies found some positive impact of using the decision support, if success is defined as achieving the desired outcomes using the CDSS. Indicating CDSS can be a valuable tool for guideline adherence in the ED if designed properly[23-27]. As the article by Roukema[27] demonstrated with poor prediction of a serious bacterial infection, the decision support tools are only as successful as the guidelines they are based on and reevaluations of the tool may be necessary after implementation.

Patient Safety and Use of CDSS

Patient safety is a key component of quality to be addressed in the emergency department with the need to reduce medical errors including triage misdiagnosis[22].

Various studies suggest the critical area of patient safety can be positively impacted with the use of CDSS in the high-risk, fast-paced environment of the ED. CDSS reduce the need to make decisions based on memory when time is limited to review appropriate guidelines, helping to create safer practices related to prescribing medications for the elderly and accurate triage scoring[28,29].

CDSS for Head CT

There is a wide variety in rates of CT utilization in Canada as well as the United States. One Canadian study demonstrated a rate of CT scan imaging ranging from 6 to 26% even

though the rate of positive CT findings were same across all hospitals included in the study[30]. Clearly, multiple clinical decision rules are emerging, and the emergency physician must try to optimize the sensitivity of the rule as well as its precision[30].

In addition, real time decision support in promoting evidence based ED care could include the following[31]:

1. The integration of clinical decision rules at the point of test ordering in the ED
2. Automated presentation of evidence based guidelines at the point of ED test ordering or treatment decisions
3. Development of nonintrusive decision support that would decrease alert fatigue
4. Timely prompts for appropriate documentation

Areas for Improvement in CDSS

When evaluating areas of the CDSS that were not successful, poor compliance from clinicians was frequently identified[24,26,29]. These findings emphasize that decision support in the EHR is a tool that can facilitate guideline adherence, but having provider support of the recommendations is critical. Involving the users in the development process, presenting the evidence for the recommendations, and addressing clinician resistance prior to implementing the tool are essential[24,29].

Workflow design of CDSS is another vital component impacting the success on improving care. Decision support systems that provide care recommendations within the usual workflow of the clinician, being integrated into the EHR and computerized physician order entry, and providing support at the time of care facilitate the use of by the clinician[21].

CT utilization

There are multiple clinical decision rules for CT utilization but no real baseline of adherence to those rules as of yet. This prompted a prospective study to determine adherence to a particular rule and then decide how to decrease variation.

Intervention

To support our objectives we implemented the following interventions:

- Engaging hospital administration and health insurance carriers on the quality benefits of decreased CT usage
- Ensuring clinicians are aware of the new PECARN guidelines and the CDS tool/BPA through email, division meetings and grand rounds presentations
- Educating triage nurses on the use of the CDS template within Epic and review plan for follow-up at staff meetings and via email
- Practice use of the CDS template in Epic during a 2 week trial period
- Go-live support: Nurse and physician champions as well as the Epic helpdesk will be available 24/7 the first week for clinician support of the new CDS tool
- Provide monthly feedback on CT rates and clinical outcomes in mild head injury cases to the ED staff

To address potential barriers:

- Clinician buy-in: education for providers and nurses through various methods outlined above, physician and nurse champions
- Clinician time: the scoring template will appear as part of the usual workflow. Providers will see the best practice alert containing the recommendation when entering the history and physical into Epic.
- Financial: to mitigate decreased revenue from less CT scan usage, we anticipate health-care plans will provide incentives for reducing costs from CT use without worsening clinical outcomes. In addition, use of this tool will allow the organization to include this process in its quality reporting, ensuring compliance with meaningful use requirements to receive incentive payments.
- Technology: the Epic system has been in place for almost three years, and most of the faculty and nursing staff have been at the hospital since the original rollout. The CDS template will be uploaded in the Epic Playground for practice use and technology support will be available 24/7 for go-live.

Methods

Study design

This study was designed as a quasi-experimental interventional study to measure the change in clinician ordering behavior associated with the introduction of a computerized decision support system for patients with minor head injury presenting to the emergency department for evaluation. For the purposes of this paper, clinician will include board certified attending pediatric emergency physicians as well as nurse practitioners. Also, patients will be synonymous with patient visits.

A head injury algorithm was designed based on a clinical decision algorithm by Kuppermann and integrated into the Epic EHR. [5] This was done in two different ways. The first was by a Best Practice Alert (BPA) and the second was through a Head Injury Navigator (HIN) that was developed by the investigators using an Epic's document flow-sheet based build.

The study was divided into pre and post intervention phases each lasting six consecutive calendar weeks. During the pre-intervention phase, clinicians used the HIN but no risk score or recommendation was given. Clinicians managed patients as usual, ordering CT imaging if it was deemed to be necessary. The post-intervention phase was identical to the pre-intervention phase except for the revelation of a risk score calculated at the end of the HIN. In addition, a recommendation was given as to whether or not a CT was recommended. If CT was not recommended the HIN would recommend "observation". There was no specific time period attached to "observation" .

Patients were included if they were thought to fit the classification of minor head injury. Patients were excluded if they had a GCS of less than 14, had a history of neurosurgical problem, had a history of hemophilia or were classified as a trauma team activation either in the field or at triage if the patient was a walk in. Trauma activations were excluded because at our institution, the ultimate decision as to whether or not the child should be imaged rests with the surgeon and not the ED clinician. Patients were also excluded if imaging studies were done at an outside facility.

An estimated sample size was calculated to be 86 patients undergoing head CT for each group (α of 0.05 and power of 80%) to demonstrate an 18% increase in clinician adherence rate between the pre and post-intervention groups. This was based on prior analysis of our department's visits.

Study Setting

The study was conducted in the emergency department of a university-affiliated children's hospital. The department is a level-one pediatric trauma center that has over 75,000 visits per year and is staffed by board-certified pediatric emergency medicine physicians and nurse practitioners. Approval of the study was obtained from both the hospital and the university institutional review board. The Epic EHR version 2009 was the platform onto which the HIN and BPA were built.

Subjects

The subjects in this study were actually the clinicians. There were 17 board certified pediatric emergency medicine physicians. Two of these physicians were trained in emergency medicine and then did PEM fellowships. The remaining 15 all did pediatric residencies before their PEM fellowships. There were 5 board certified pediatricians all of whom have worked in the emergency department for over 4 years. In addition, there were 6 nurse practitioners who worked exclusively in the emergency department.

Selection of Patients

Through an iterative process, rules were developed and written to capture various chief complaints that could be possibly related to head injury. (Fig 2)

A BPA alert was set to fire if any of the selected complaints were matched on an OR condition.

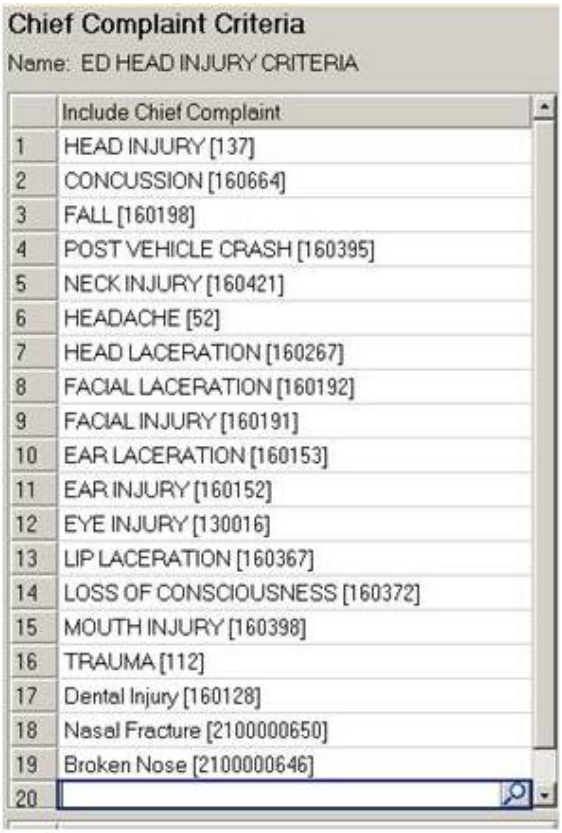

Figure 2

The BPA presented the user with three different options; cancel, complete head injury section or low risk head injury unlikely. (Fig 3) Cancel could be used at any time to ignore the BPA and search the chart for more details but unless another action was taken, every time the user reopened the chart the BPA would again fire. If the user felt the patient did not fit the parameters for the study then he or she could choose the low risk head injury unlikely radio button and the BPA disappears permanently from that particular record. If the user chose "complete head injury section" he or she would be taken to a new section of the chart where a series of questions are asked and using branching logic or what in Epic calls 'document flow-sheet cascades', which depending on the answers to the questions takes the user through until a natural stopping point.

If the BPA did not fire but the clinician felt the child fit criteria for the study then it was also possible to access the HIN in the navigator field.

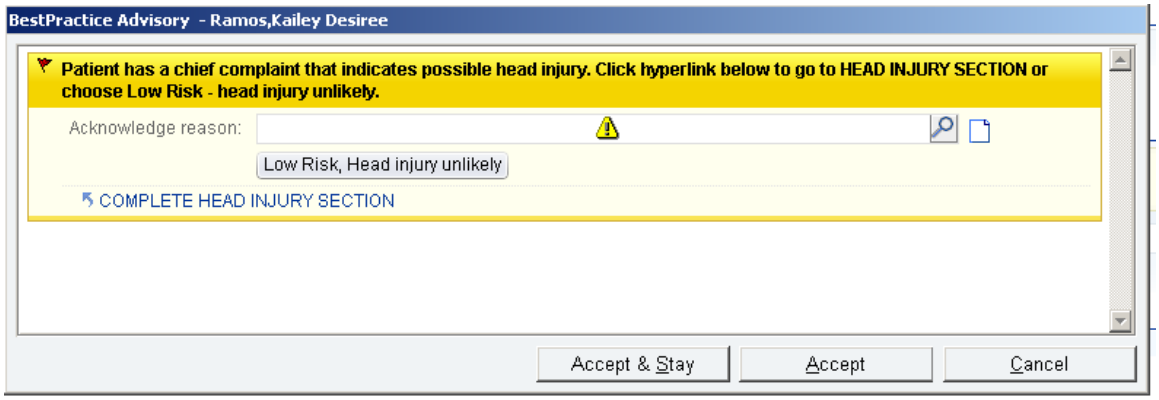

Fig 3

The logic for the HIN is presented in appendix 3. The flow-sheet includes both algorithms for the less than 2 and greater than 2 year old child.

Adherence was defined as follows:

1. If the recommendation was CT and the record showed a CT completion time

2. If the recommendation was No CT and the record showed no CT completion time

3. If the recommendation was Consider Observation and either no CT order or CT order greater than one hour post HIN entry time

(note: times are all within one patient encounter)

Patients of all ages and chief complaints were tested to be certain that the BPA fired appropriately and that the head injury navigator followed the algorithm exactly. The BPA and head injury template were trialed in a test environment for four weeks prior to commencing the study. In addition, these elements were moved into a live environment for a two week pilot period to assure that the BPA was firing appropriately and that the head injury navigator appeared for the appropriate providers.

All attending providers and nurse practitioners working in the emergency department signed an informed consent form to be involved in the study.

Figures 4 and 5 are screenshots demonstrating the head injury assessment tool. Figure 4

was used during the pre-intervention period. Figure 5 was utilized during the post-intervention period.

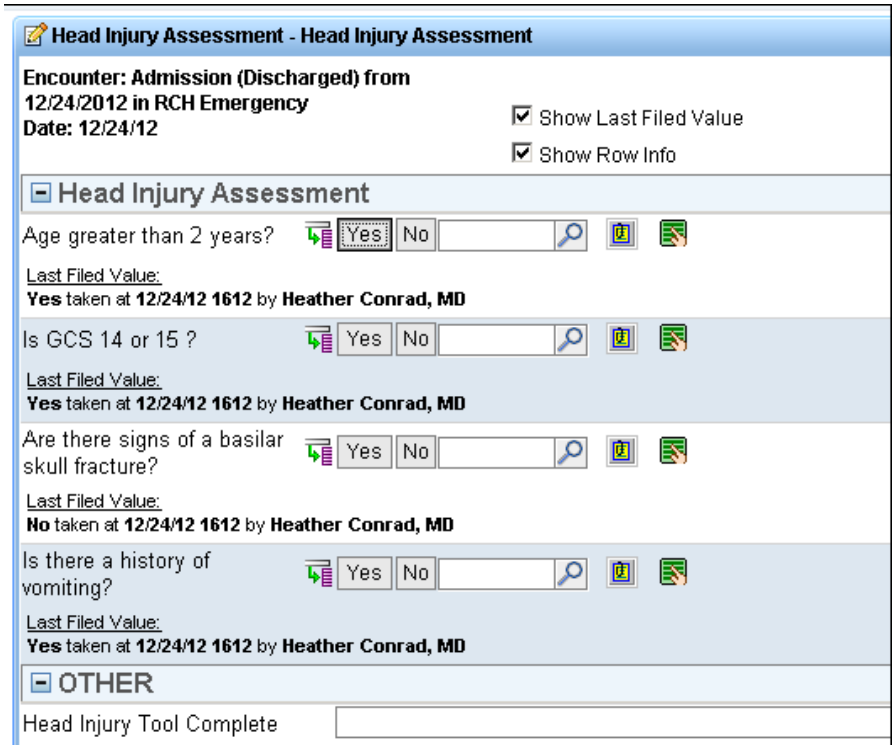

Figure 4

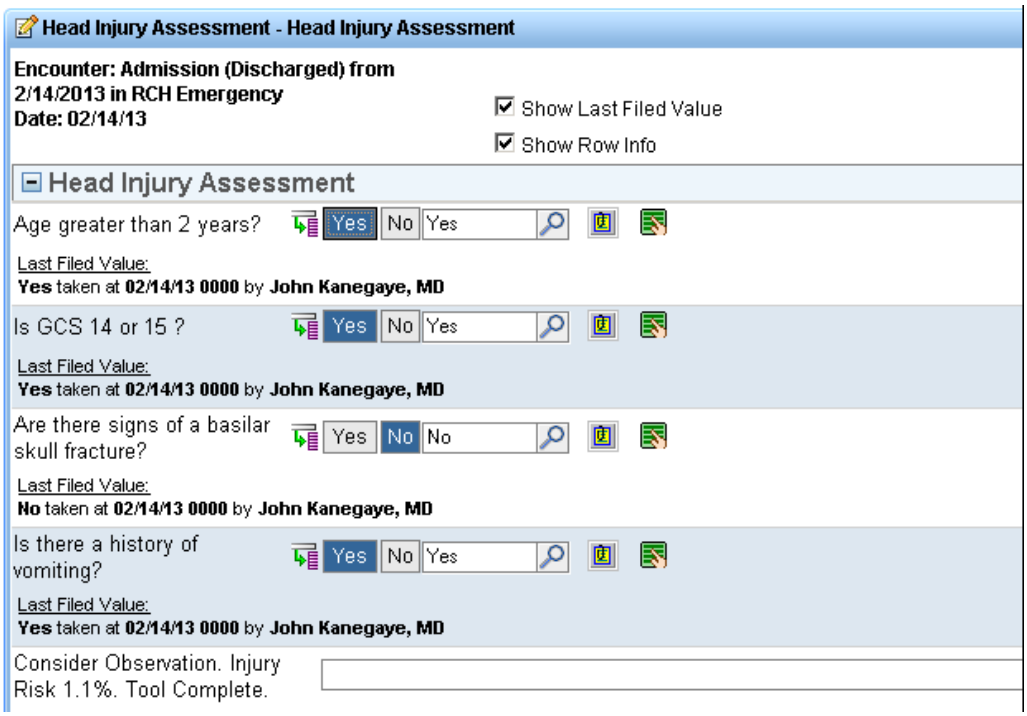

Figure 5

Note that in figure 4 that the user answers a variety of pointed questions and eventually gets prompted with Head Injury Tool complete but no risk is revealed. In figure 5, the user is given the risk and a recommendation for treatment. Also, note that the build was constructed in such a way that the user's answers were not changeable once entered. Also note that the user's entries were time stamped with the date and time.

See appendix 1 and appendix 2 for swim-lane flowcharts for both pre and post intervention pieces of the study.

Outcomes

The main outcome of interest was the proportion of clinicians adhering to the guideline before the intervention as compared to the proportion of clinicians adhering to the guideline after the intervention. The intervention was the risk of c-TBI being made available to the clinician through the HIN. Secondary outcomes included the number of CT scans ordered as well as length of stay (LOS) difference between phases . In addition adherence within the two age groups of the algorithm will also be examined.

Analysis

Statistics were done using the R Project for Statistical Computing. A Welch t-test was used to analyze excluded vs. included subjects. The primary outcome of 'adhered' was compared between the pre and post intervention groups using a marginal logistic regression model. The intervention group was a categorical covariate and a compound symmetry (also called 'uniform' or 'exchangeable') working correlation structure was used to model the dependency between patients who shared a clinician. A Wald test of the coefficient of intervention group was used to determine if the odds of adherence to the rule is significantly different after intervention.

Results:

The BPA fired 2,404 times during the study period. The HIN was completed 674 times.

31 patients were excluded leaving 641 patients for analysis. The majority of exclusions were due to patients being trauma team activations. The remaining patients were excluded because the clinician incompletely filled out the HIN.

Table 1 shows the demographic data and acuity level for both pre and post intervention groups. Acuity level 1 is the highest acuity and level 5 is the lowest. Patients age, sex and acuity level were not found to be significantly different between the two groups. Also, note that the majority of patients fell into the acuity levels 3 and 4. This follows as the patients of interest were in the "minor" head injury category and thus would not have expected to see many high acuity patients.

	N	Pre $N = 404$	Post $N = 237$	Combined $N = 641$	P-value
Age (years)	641	6.15 (5.06)	6.29 (5.31)	6.20 (5.15)	0.743[1]
Sex	641				0.776[2]
Female		158 (39%)	90 (38%)	248 (39%)	
Male		246 (61%)	147 (62%)	393 (61%)	
Acuity Level	640				0.506[2]
1		2 (0%)	2 (1%)	4 (1%)	
2		59 (15%)	46 (19%)	105 (16%)	
3		143 (35%)	85 (36%)	228 (36%)	
4		174 (43%)	91 (38%)	265 (41%)	
5		25 (6%)	13 (5%)	38 (6%)	

Mean (SD) for continuous variables.
N is the number of non–missing values.
Tests used:
[1]t test; [2]Pearson test

Table 1

	N	Pre $N = 404$	Post $N = 237$	Combined $N = 641$
Adhered	641			
No		76 (19%)	34 (14%)	110 (17%)
Yes		328 (81%)	203 (86%)	531 (83%)
Length of Stay (mins)	641	201 (169)	218 (109)	207 (150)
CT	641			
No		334 (83%)	201 (85%)	535 (83%)
Yes		70 (17%)	36 (15%)	106 (17%)

Mean (SD) for continuous variables.
N is the number of non–missing values.

Table 2

	No. Clinicians	No. Patients	OR (95% CI)	p-value
Adhered	27	641	1.345 (0.987-1.835)	0.061
CT	27	641	0.858 (0.634-1.161)	0.321

Table 3

Table 2 shows descriptive statistics by intervention group. Note that "adhered" means adherence to the clinical decision rule and CT indicates whether imaging was obtained.

Adherence was higher in the post intervention group 328 patients (81%) as compared to 203 patients (86%) although not statistically significant. CT imaging was higher in pre intervention group (17%) as compared to the post intervention group (15%) but again these were not statistically significant.

Table 3 shows the results of pre vs. post intervention group comparisons. The first column is the number of clinicians with at least one patient in the study while the second column is the number of patients in the study. The estimated odds ratio (95% confidence interval) is the estimated odds of adherence to the rule for the post intervention group divided by the estimated odds for the pre intervention group. The p-values were obtained from Wald tests of the null hypothesis that the OR was 1.

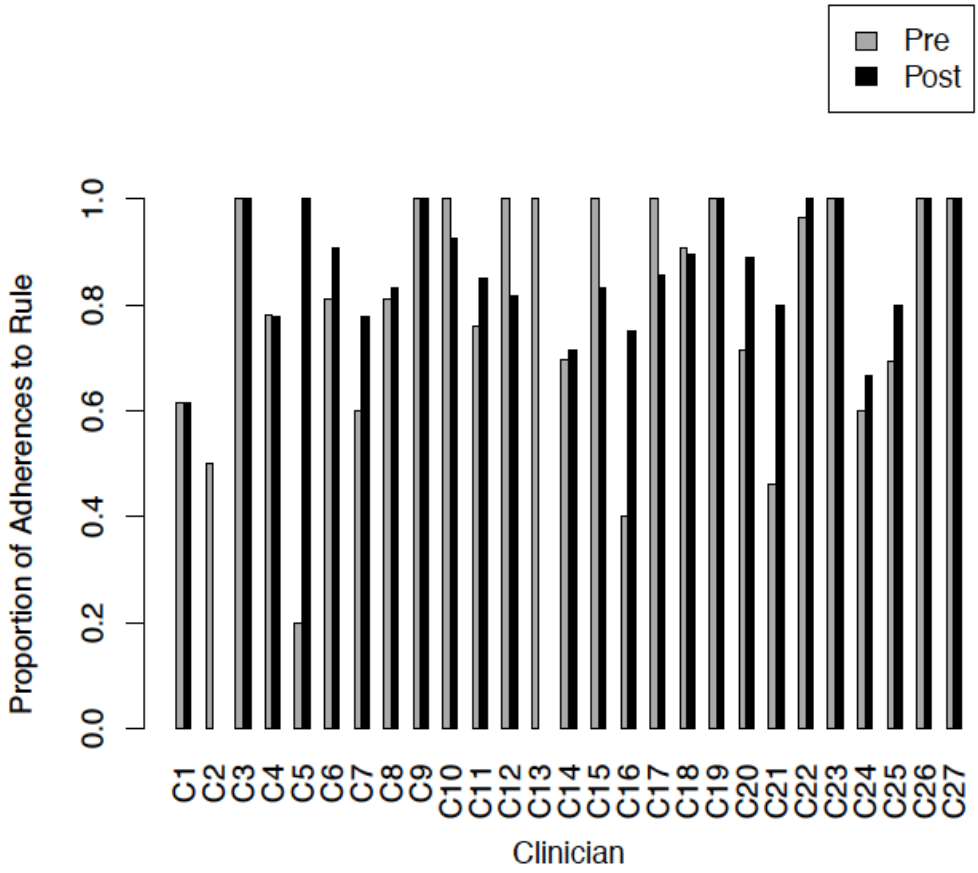

Figure 6

Figure 6 shows the proportion of adherence by clinician. Note that some providers did not see included patients during both periods.

Discussion

The study has shown no significant difference in adherence between both pre and post intervention groups. The reasons for this may be multivariate in origin. First, the group of clinicians that we studied are all specialists in the field of pediatric emergency medicine. The study took place at an academic medical center where residents, fellows and students all see patients and are learning clinical practice guidelines. All providers were aware of the PECARN clinical practice guideline published by Kuppermann.[5] This may account for why there was not a statistically different difference with our intervention. This finding is not a new one in the era of clinician acceptance of CDSS. Lomotan studied a CDSS with another pediatric subspecialty of pulmonology. [34] It was found that there was variable acceptance amongst subspecialists.

CDSS does not always translate into improved outcome or improved rates of adherence to clinical practice guidelines. Garg examined 100 studies involving CDSS systems and discovered a wide variety of outcomes. [35] Important lessons learned were user acceptance, clinical workflow integration and efficiency. Ever increasing pressures to lower throughput times combined with improving RVU performance may also contribute to clinicians ignoring clinical alerts. Alert fatigue may have also played a role as many triage chief complaints were included that may not have had anything to do with a head injury.

This study attempted to follow the Ten Commandments for Effective Clinical Decision Support as outlined by Dr. Bates. [36] Some might argue that a lower rate of compliance to using the HIN was due to not having a hard stop on the alert. As Bates explains, physicians strongly resist stopping and prefer to be given alternatives. The BPA used in this study included a "cancel" button so that the user could examine the chart or return to the patient to make certain to answer the question posed accurately. The tradeoff is that some clinicians never acknowledged the BPA beyond cancelling it despite the fact that it would fire each time the provider opened the chart. This may have resulted in noncompliance with filling out the HIN an subsequently the CDSS would not have been utilized.

There were limitations working in the Epic environment. The BPA graphical interface was limited to the box seen in fig. 3. The user needed two mouse clicks in order to arrive at the HIN. The size of link could not be changed, and the HIN could not be built directly into the BPA.

The next step is to further refine our model. This follows the Plan-Do-Study-Act cycle which is part of the Institute of Healthcare Improvement Model. After the analysis of the model, it is now appropriate to refine the change on what was learned from the model and launch back into the planning part of cycle once again.

Also, a qualitative study might be helpful in trying to better understand the mindset of the clinicians when faced with clinical alerts and how this affected their decision making.

Conclusion

The study showed no statistical difference with our intervention. The reasons for this are likely multifactorial. Future refinement might include finding a more effective way to integrate the CDSS into the clinical workflow. Perhaps this can be done without alerts. Natural language processing might also help identify those patients in which clinical practice guidelines might apply.

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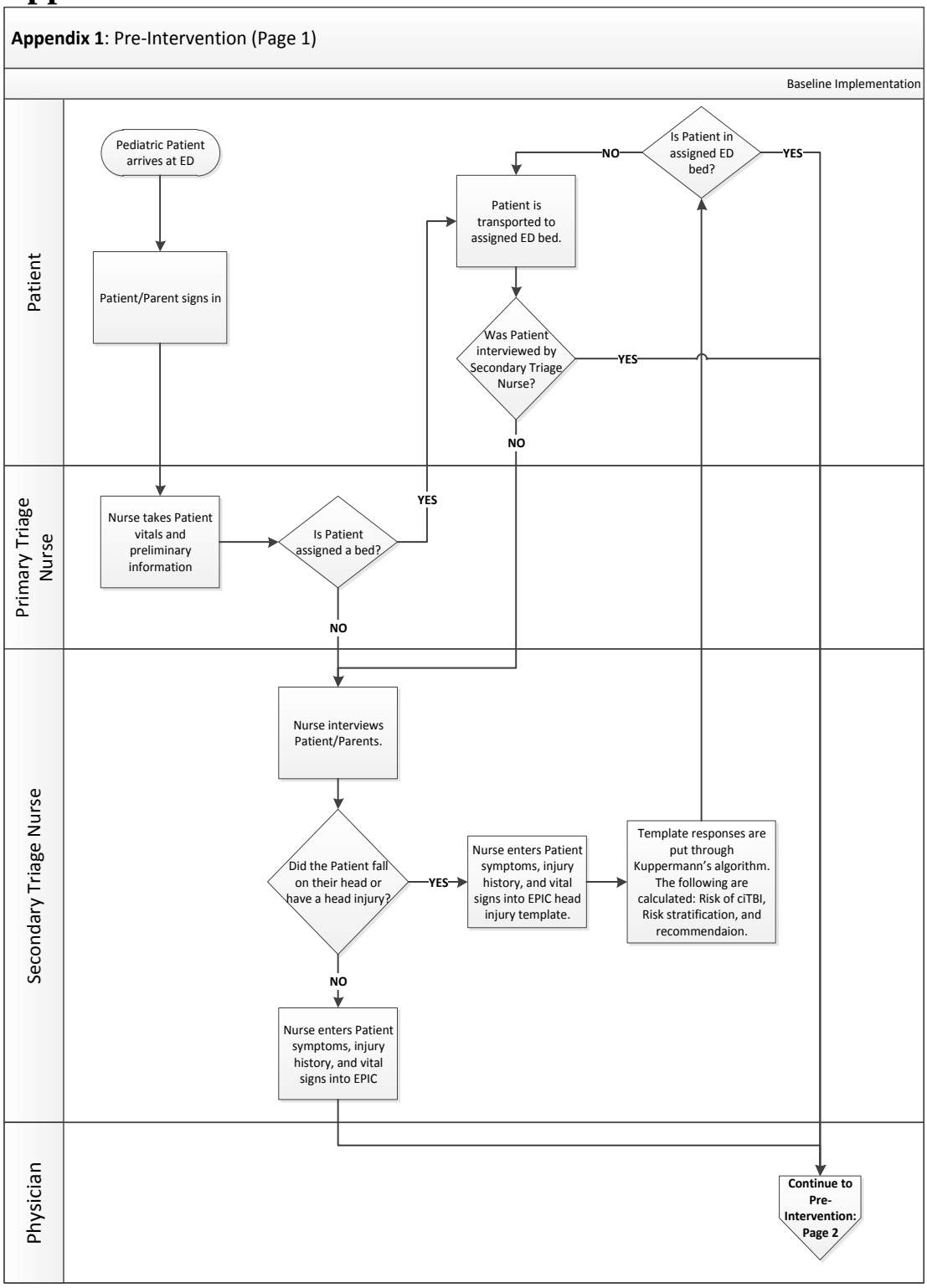
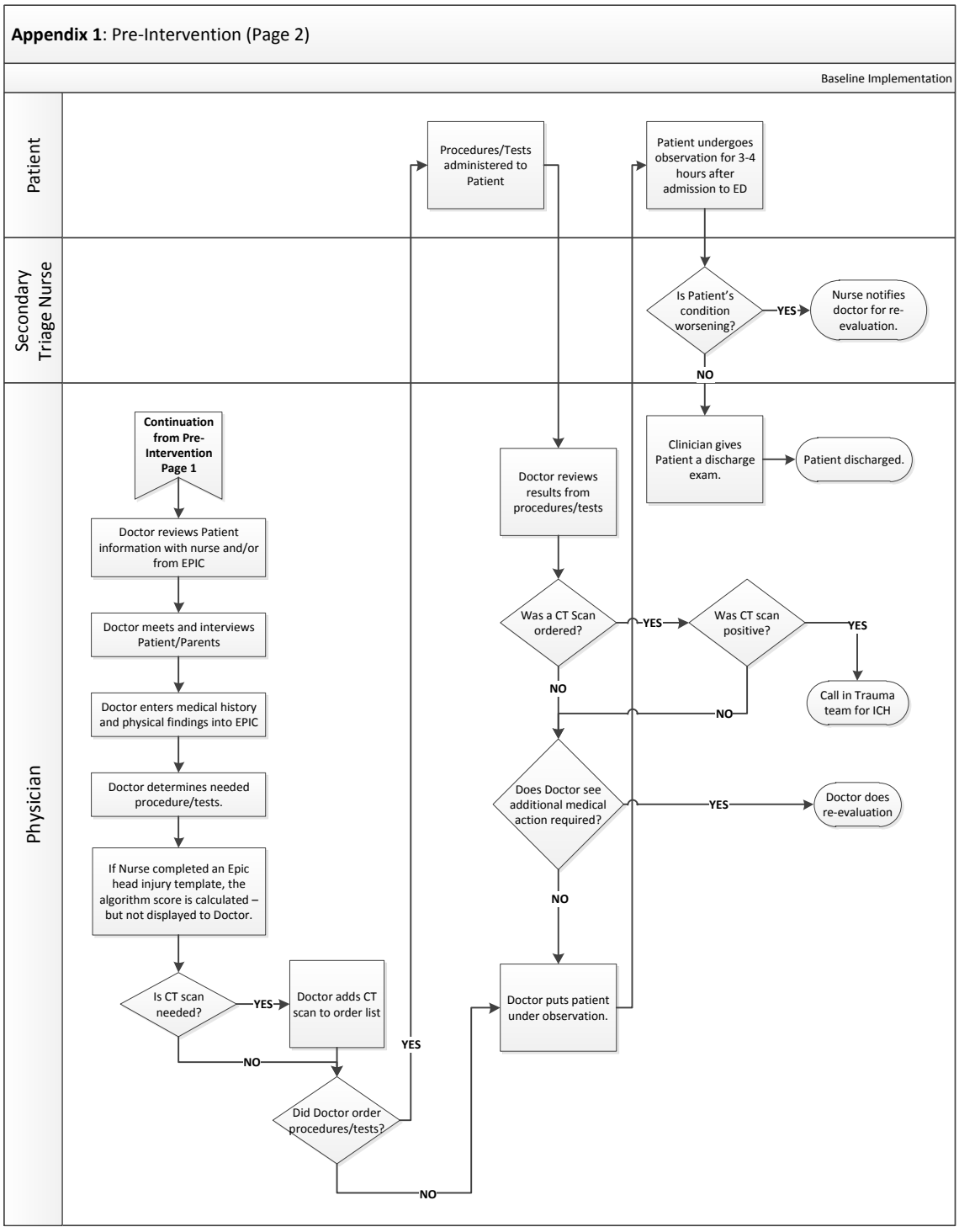
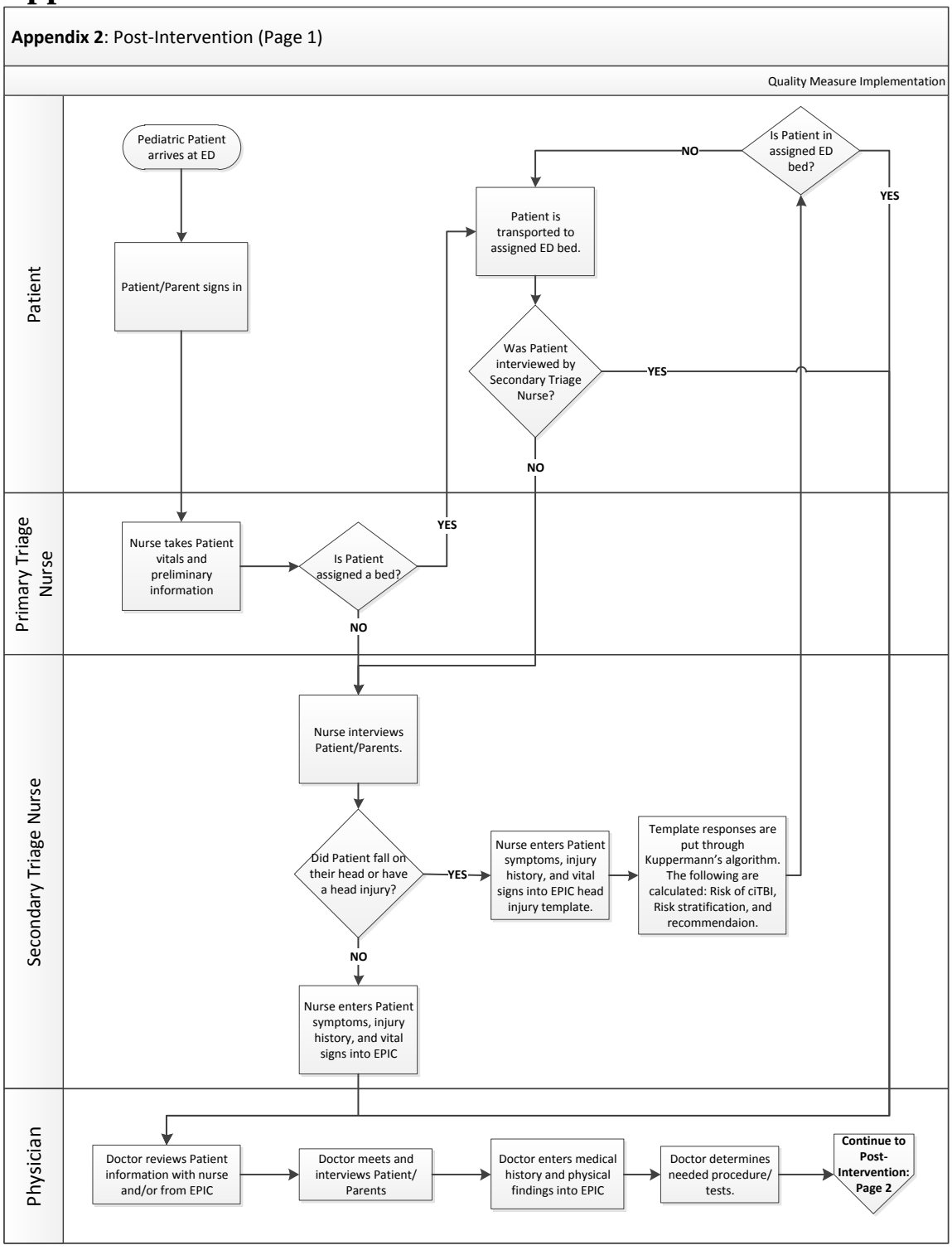
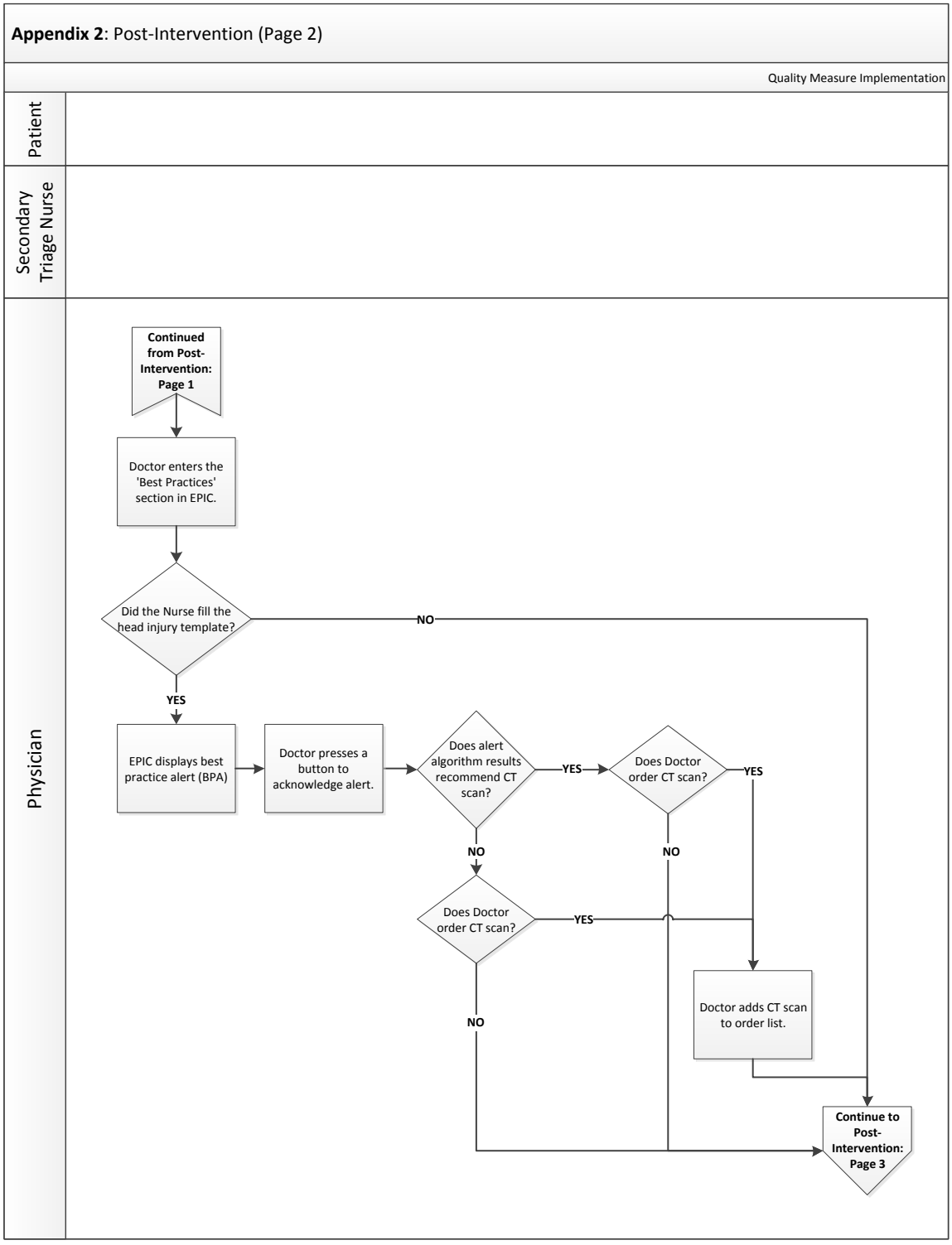
Appendix 1


Appendix 1: Pre-Intervention (Page 1)
Baseline Implementation
Patient
Primary Triage Nurse
Secondary Triage Nurse
Physician
Pediatric Patient arrives at ED
Patient/Parent signs in
Nurse takes Patient vitals and preliminary information
Is Patient assigned a bed?
YES
NO
Patient is transported to assigned ED bed.
Is Patient in assigned ED bed?
NO
YES
Was Patient interviewed by Secondary Triage Nurse?
YES
NO
Nurse interviews Patient/Parents.
Did the Patient fall on their head or have a head injury?
YES
NO
Nurse enters Patient symptoms, injury history, and vital signs into EPIC head injury template.
Template responses are put through Kuppermann's algorithm. The following are calculated: Risk of ciTBI, Risk stratification, and recommendaion.
Nurse enters Patient symptoms, injury history, and vital signs into EPIC
Continue to Pre-Intervention: Page 2

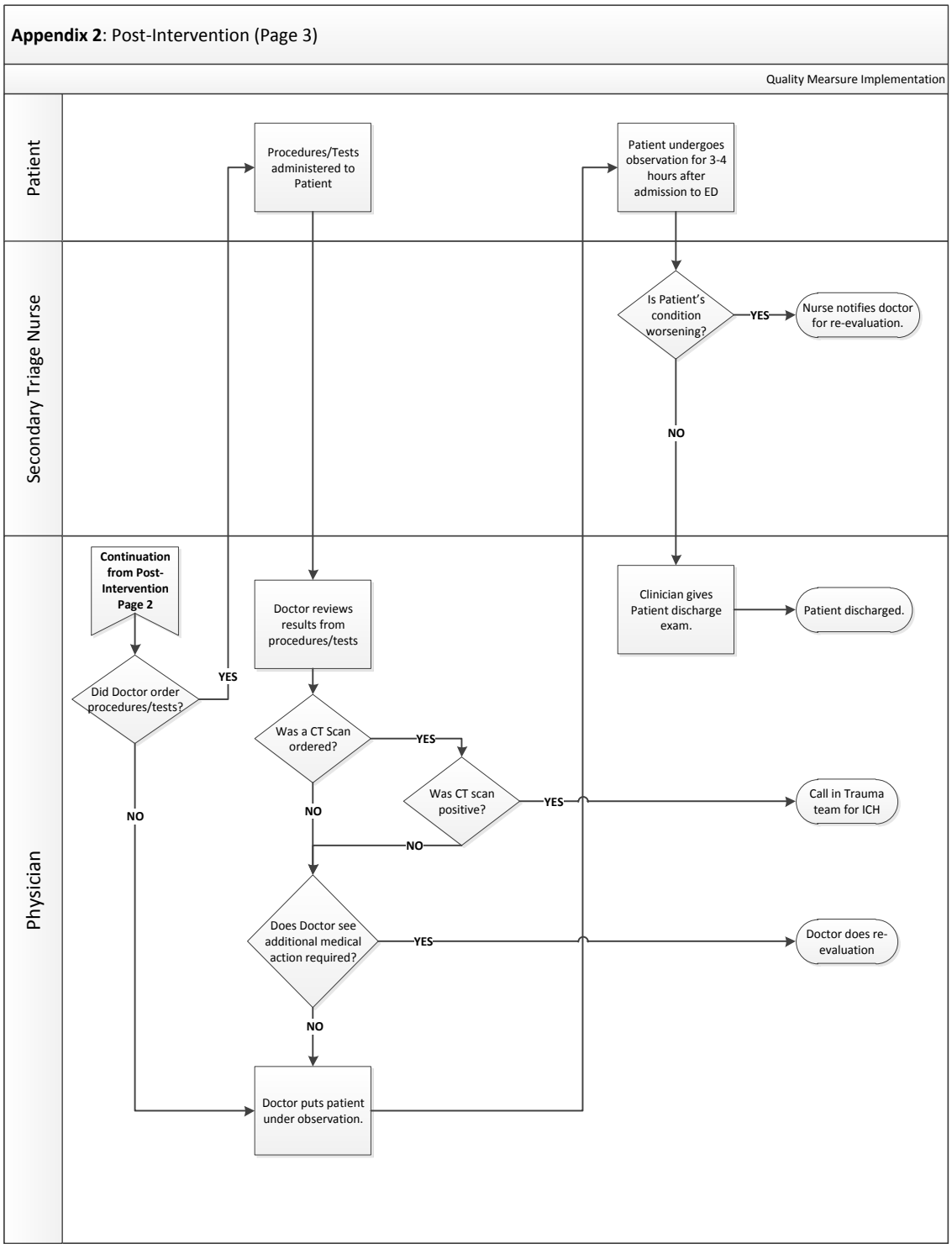

Appendix 1: Pre-Intervention (Page 2)
Baseline Implementation
Patient
Secondary Triage Nurse
Physician
Procedures/Tests administered to Patient
Patient undergoes observation for 3-4 hours after admission to ED
Is Patient's condition worsening?
YES
Nurse notifies doctor for re-evaluation.
NO
Clinician gives Patient a discharge exam.
Patient discharged.
Continuation from Pre-Intervention Page 1
Doctor reviews Patient information with nurse and/or from EPIC
Doctor meets and interviews Patient/Parents
Doctor enters medical history and physical findings into EPIC
Doctor determines needed procedure/tests.
If Nurse completed an Epic head injury template, the algorithm score is calculated – but not displayed to Doctor.
Is CT scan needed?
YES
Doctor adds CT scan to order list
NO
Did Doctor order procedures/tests?
YES
NO
Doctor reviews results from procedures/tests
Was a CT Scan ordered?
YES
Was CT scan positive?
YES
Call in Trauma team for ICH
NO
NO
Does Doctor see additional medical action required?
YES
Doctor does re-evaluation
NO
Doctor puts patient under observation.

Appendix 2

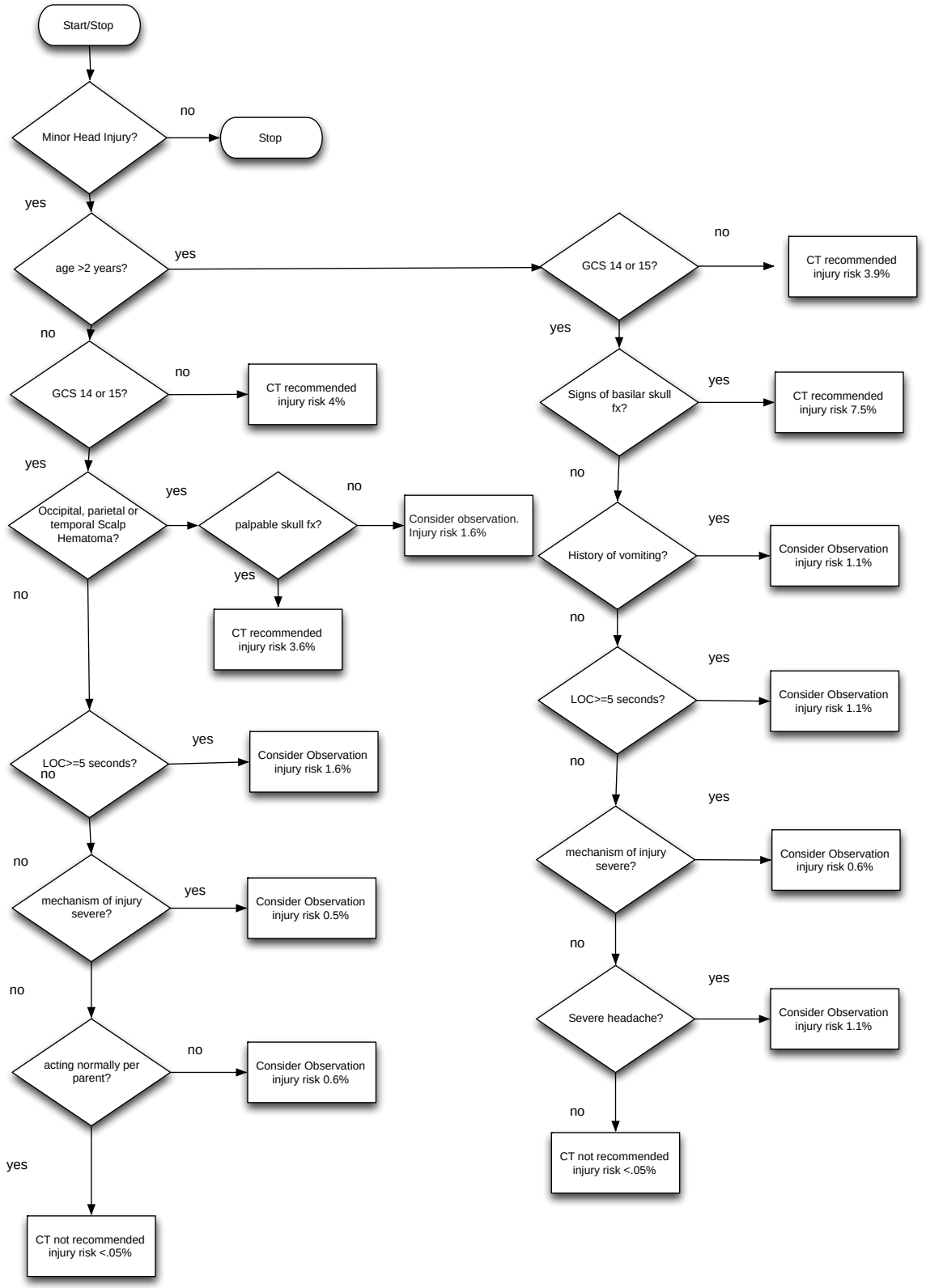

Appendix 2: Post-Intervention (Page 1)
Quality Measure Implementation
Patient
Primary Triage Nurse
Secondary Triage Nurse
Physician
Pediatric Patient arrives at ED
Patient/Parent signs in
Nurse takes Patient vitals and preliminary information
Is Patient assigned a bed?
YES
NO
Patient is transported to assigned ED bed.
Is Patient in assigned ED bed?
NO
YES
Was Patient interviewed by Secondary Triage Nurse?
YES
NO
Nurse interviews Patient/Parents.
Did Patient fall on their head or have a head injury?
YES
Nurse enters Patient symptoms, injury history, and vital signs into EPIC head injury template.
Template responses are put through Kuppermann's algorithm. The following are calculated: Risk of ciTBI, Risk stratification, and recommendaion.
NO
Nurse enters Patient symptoms, injury history, and vital signs into EPIC
Doctor reviews Patient information with nurse and/or from EPIC
Doctor meets and interviews Patient/ Parents
Doctor enters medical history and physical findings into EPIC
Doctor determines needed procedure/ tests.
Continue to Post-Intervention: Page 2


Appendix 2: Post-Intervention (Page 2)
Quality Measure Implementation
Patient
Secondary Triage Nurse
Physician
Continued from Post-Intervention: Page 1
Doctor enters the 'Best Practices' section in EPIC.
Did the Nurse fill the head injury template?
NO
YES
EPIC displays best practice alert (BPA)
Doctor presses a button to acknowledge alert.
Does alert algorithm results recommend CT scan?
YES
Does Doctor order CT scan?
YES
NO
NO
Does Doctor order CT scan?
YES
NO
Doctor adds CT scan to order list.
Continue to Post-Intervention: Page 3

Appendix 2: Post-Intervention (Page 3)



Appendix 3


Start/Stop
Minor Head Injury?
no
Stop
yes
age >2 years?
yes
GCS 14 or 15?
no
CT recommended injury risk 3.9%
yes
Signs of basilar skull fx?
yes
CT recommended injury risk 7.5%
no
History of vomiting?
yes
Consider Observation injury risk 1.1%
no
LOC>=5 seconds?
yes
Consider Observation injury risk 1.1%
no
mechanism of injury severe?
yes
Consider Observation injury risk 0.6%
no
Severe headache?
yes
Consider Observation injury risk 1.1%
no
CT not recommended injury risk <.05%
no
GCS 14 or 15?
no
CT recommended injury risk 4%
yes
Occipital, parietal or temporal Scalp Hematoma?
yes
palpable skull fx?
no
Consider observation. Injury risk 1.6%
yes
CT recommended injury risk 3.6%
no
LOC>=5 seconds?
yes
Consider Observation injury risk 1.6%
no
mechanism of injury severe?
yes
Consider Observation injury risk 0.5%
no
acting normally per parent?
no
Consider Observation injury risk 0.6%
yes
CT not recommended injury risk <.05%