Evaluation for Occult Fractures in Injured Children

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abstract

OBJECTIVES: To examine variation across US hospitals in evaluation for occult fractures in (1) children <2 years old diagnosed with physical abuse and (2) infants <1 year old with injuries associated with a high likelihood of abuse and to identify factors associated with such variation.

METHODS: We performed a retrospective study in children <2 years old with a diagnosis of physical abuse and in infants <1 year old with non-motor vehicle crash-related traumatic brain injury or femur fractures discharged from 366 hospitals in the Premier database from 2009 to 2013. We examined across-hospital variation and identified child- and hospital-level factors associated with evaluation for occult fractures.

RESULTS: Evaluations for occult fractures were performed in 48% of the 2502 children with an abuse diagnosis, in 51% of the 1574 infants with traumatic brain injury, and in 53% of the 859 infants with femur fractures. Hospitals varied substantially with regard to their rates of evaluation for occult fractures in all 3 groups. Occult fracture evaluations were more likely to be performed at teaching hospitals than at nonteaching hospitals (all $P < .001$). The hospital-level annual volume of young, injured children was associated with the probability of occult fracture evaluation, such that hospitals treating more young, injured patients were more likely to evaluate for occult fractures (all $P < .001$).

CONCLUSIONS: Substantial variation in evaluation for occult fractures among young children with a diagnosis of abuse or injuries associated with a high likelihood of abuse highlights opportunities for quality improvement in this vulnerable population.

WHAT'S KNOWN ON THIS SUBJECT: Screening for occult fractures is a key component of the medical evaluation for young victims of suspected physical abuse. Little is known about adherence to occult fracture evaluation guidelines in children with suspected abuse cared for at non-pediatric-focused hospitals.

WHAT THIS STUDY ADDS: Occult fracture evaluations were performed in half of young children diagnosed with abuse or injuries concerning for abuse in a large cohort of hospitals. Evaluations were more common at hospitals caring for higher volumes of young, injured children.

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Evaluation for occult fractures with a skeletal survey (SS) is a key component of the evaluation of young children with injuries from suspected physical abuse. SSs reveal fractures that are not clinically suspected on the basis of history or physical examination in 10% to 40% of children <2 years old evaluated for suspected abuse.¹⁻⁶ In addition to identifying fractures requiring medical treatment, SSs can document fractures and other findings that do not require medical treatment but are important to safeguard the well-being of the child. Specific patterns of fractures can confirm a diagnosis of abuse and allow for protection of the child.⁷ The stage of healing of the fractures can provide information regarding the timing of the abuse and aid in perpetrator identification.⁷ The American Academy of Pediatrics recommends that SSs be performed in all cases of suspected physical abuse in children <2 years old.^{7,8}

Despite these recommendations, research suggests that SSs are not uniformly performed in cases of suspected abuse in children <2 years old. A study in children <2 years old diagnosed with abuse at 40 US children's hospitals found that, overall, the majority of children (83%) received an SS, but rates varied from 55% to 93% across hospitals.⁹ Even greater variation in SS performance was observed among infants <1 year old with non-motor vehicle crash (MVC)-related femur fractures or traumatic brain injuries (TBIs). Although national guidelines regarding SS performance in infants with non-MVC-related TBI and femur fractures do not exist, these specific injuries are associated with a high likelihood of abuse. Estimates of the rate of suspected or confirmed diagnosis of abuse among infants with non-MVC-related femur fractures range from 17% to 68%.¹⁰⁻¹⁶ The rate of diagnosis of abuse among infants with non-MVC-related TBI ranges from 33% to 95%.¹⁷⁻¹⁹ The observed low rate of

occult fracture evaluation in these high-risk infants at some pediatric hospitals raises concern for missed opportunities to detect abuse.

Research on occult fracture evaluation practices in the United States has focused on children's hospitals; the majority of injured children, however, receive care at general hospitals, which are less likely to have specialized child abuse consultants than pediatric centers. A study using nationally representative hospital data found that infants with non-MVC-related femur fractures or TBIs were less likely to receive an abuse diagnosis at general hospitals than at pediatric hospitals, suggesting that infants at general hospitals may be underdiagnosed with abuse.¹² Studies

outside the United States have also raised concerns about occult fracture evaluation practices at general hospitals. An Australian study found that occult fracture evaluations were performed in less than half of children <2 years old treated for fractures at a general hospital.²⁰ A survey of European Society of Pediatric Radiology members revealed significant variation in imaging protocols for suspected abuse across institutions.²¹

Given concerns regarding occult fracture evaluation practices, we examined the rate of occult fracture evaluation in a large cohort of US hospitals. The primary goals of this study were to quantify variation in and determine factors associated with

FIGURE 1 Process by which the final cohort of subjects was selected. First, encounters for injuries that were clearly nonabusive were excluded. Second, encounters with hospital-to-hospital transfers were excluded in case occult injury evaluations performed at outside hospitals. Last, encounters were limited to 1 encounter/patient per month with complete data on imaging and gender. ED, emergency department.

evaluation for occult fractures across the hospitals in (1) children <2 years old diagnosed with physical abuse and (2) infants <1 year old with injuries associated with a high likelihood of abuse. In particular, the analysis focused on identifying child- and hospital-level factors associated with evaluation for occult fractures, including a hospital's annual volume of treated children.

METHODS

Data Source

We used the Premier Perspective Database (Premier, Inc, Charlotte, NC), a large all-payer database that includes inpatient and hospital-based outpatient encounter data from >2000 participating academic medical centers, community-based hospitals, and large multihospital systems.^{22,23} Approximately 20% of the nation's acute care hospitalizations with ~5.5 million hospital discharges are captured annually.^{24,25} Hospitals submit encounter data, including patient demographic characteristics, diagnoses, and resource utilization, to the Premier Perspective Database. We limited our analysis to the 6 279 685 inpatient and emergency department encounters for children <2 years old with discharge dates between 2009 and 2013 at hospitals reporting data from both inpatient and emergency department encounters. This study did not require institutional review board approval because it did not meet the definition of human subjects research.

Study Population

The study population included (1) children <2 years old diagnosed with physical abuse and (2) infants <1 year old with high-risk injuries. Classification in the abuse group was determined by the presence of an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), diagnosis code or external cause of injury code

for physical abuse or assault. The high-risk injury group included infants with ICD-9-CM codes for serious injuries frequently attributed to abuse, specifically non-MVC-related TBIs and femur fractures^{9,12} (see Supplemental Table 4 for a listing of included ICD-9-CM codes). The TBI group included infants with intracranial hemorrhage, cerebral contusions, and/or lacerations. Infants with skull fractures without intracranial hemorrhage were not included in the TBI group, because the risk of abuse and occult fractures is lower in this population.^{18,26–29} Patients with diagnoses of both femur fracture and TBI were categorized on the basis of which injury received imaging first. Infants in the femur and TBI groups were also included in the abuse group if they received a diagnosis of abuse. We excluded children with MVC- or birth-related trauma, transfer(s) to/from other hospitals (in case they had an SS performed at an outside hospital), bone disorders in infants with femur fractures, and bleeding disorders in infants with TBI (Fig 1). For patients with multiple encounters within the same month, only the first encounter was included and subsequent

encounters were dropped. Infants were also excluded if we were unable to determine which injury was imaged first and could not assign them to an injury group (femur or TBI) or if gender was missing. We had a final cohort of 4486 children.

Study Outcomes

The primary outcome for our analysis, evaluation for occult fractures, was determined on the basis of descriptions of the diagnostic imaging studies associated with each encounter. We aimed to be as inclusive as possible in categorizing which radiologic studies (or groups of studies) might have been performed to evaluate for occult fractures. Thus, we included not only complete SSs but also limited SSs, radionuclide bone scans, and groups of radiographs that covered the main body regions (skull, spine, upper and lower extremities, abdomen/pelvis, and chest), recognizing that not all of these imaging studies conform to the standards set by the American College of Radiology.³⁰ For patients with additional encounters of any type occurring within the same 1-month period as the index encounter, we aggregated the

TABLE 1 Demographic and Clinical Characteristics of the Study Population

Characteristic	Physical Abuse (n = 2502)	High-Risk Injury Infant Groups ^a (n = 2433)	
		TBI (n = 1574)	Femur Fracture (n = 859)
Age <1 year old, %	64	100	100
Male gender, %	56	58	52
Race, %			
White, non-Hispanic	45	51	48
Black	25	19	27
Hispanic	6	7	5
Other/unknown	25	24	20
Insurance, %			
Private	12	28	30
Government	86	69	67
Other/unknown	2	4	3
Injury severity score, ^b %			
Mild/moderate	—	19	96
Severe	—	81	4
Diagnosis of physical abuse, %	100	22	12
Died, %	2	3	<1

—, not applicable.
^a Three infants with both TBIs and femur fractures were excluded due to inability to determine order of imaging of injuries.
^b ICD-9-CM–based Abbreviated Injury Scores were calculated for the head region for the infants with TBIs and for the lower extremities for the infants with femur fractures. Scores were categorized as follows for TBI: mild/moderate (1–3), severe (4–6). Scores were categorized as follows for femur fracture: mild/moderate (1–2), severe (3).

TABLE 2 Predictors of Evaluation for Occult Fractures

	Physical Abuse (n = 2502)	Infants With TBI (n = 1574)	Infants With Femur Fracture (n = 859)
Child-level predictors			
Age			
≥1 to <2 years old	Reference	—	—
0 to <1 year old	2.79 (2.30–3.37)	—	—
Gender			
Female	Reference	Reference	Reference
Male	1.17 (0.99–1.39)	1.16 (0.98–1.37)	1.18 (0.90–1.55)
Race/ethnicity			
White	Reference	Reference	Reference
Black	0.48 (0.36–0.64)	1.16 (0.74–1.82)	1.72 (1.10–2.68)
Hispanic	1.09 (0.68–1.76)	1.51 (0.87–2.61)	1.43 (0.83–2.47)
Other/unknown	0.79 (0.61–1.03)	1.71 (1.18–2.49)	1.44 (0.94–2.20)
Insurance			
Private	Reference	Reference	Reference
Government	1.12 (0.81–1.56)	2.38 (1.73–3.25)	1.44 (1.06–1.96)
Severe injury ^a	—	1.88 (1.38–2.55)	0.95 (0.45–1.98)
Year			
2009	Reference	Reference	Reference
2010	1.14 (0.82–1.60)	1.41 (0.97–2.04)	0.84 (0.51–1.37)
2011	1.24 (0.92–1.67)	1.27 (0.82–1.95)	0.75 (0.47–1.21)
2012	1.11 (0.82–1.50)	0.99 (0.68–1.44)	0.61 (0.3–0.99)
2013	0.88 (0.66–1.18)	1.27 (0.75–2.16)	0.81 (0.49–1.32)
Hospital-level predictors ^b			
Injury volume ^c	1.52 (1.31–1.77)	1.52 (1.32–1.75)	1.47 (1.20–1.80)
Hospital setting			
Rural	Reference	Reference	Reference
Urban	1.38 (0.87–2.19)	1.14 (0.63–2.10)	1.01 (0.51–2.00)
Teaching status			
Nonteaching	Reference	Reference	Reference
Teaching	1.59 (1.15–2.20)	1.64 (1.12–2.38)	2.97 (1.95–4.51)
Geographic region			
Midwest	Reference	Reference	Reference
Northeast	1.09 (0.52–2.27)	0.49 (0.19–1.27)	0.69 (0.31–1.57)
South	1.72 (1.14–2.59)	0.99 (0.57–1.74)	1.17 (0.66–2.08)
West	1.30 (0.81–2.09)	0.96 (0.56–1.65)	0.56 (0.30–1.03)

Data are presented as ORs (95% CIs). Results were generated from logistic regression models. —, not applicable.

^a For the infant TBI group, severe injury includes cases with ICD-9-CM–based Abbreviated Injury Scores for the head region of >4. For the infant femur fracture group, severe injury includes cases with ICD-9-CM Abbreviated Injury Scores for the lower extremity region of >2.

^b The analysis included data from 332 hospitals (250 urban, 93 teaching) for the abuse group, 174 hospitals (134 urban, 56 teaching) for the TBI group, and 213 hospitals (163 urban, 63 teaching) for the femur fracture group.

^c Evaluates whether log-transformed annual pediatric injury volume was associated with the odds of occult fracture evaluation.

imaging data from all of the encounters into the index encounter. Thus, an evaluation for occult fractures was categorized as having been performed if an evaluation was

done during any encounter occurring that month (a generous categorization that would bias findings toward higher rates of occult fracture screening).

TABLE 3 Adjusted Occult Fracture Evaluation Rates by Mean Annual Hospital Pediatric Injury Volume

Group	Mean Annual Hospital Injury Volume (encounters), % (95% CI)			
	250	500	1000	2000
Abuse	40 (36–44)	49 (46–53)	58 (53–64)	67 (59–75)
Infant TBI	39 (33–45)	48 (44–53)	58 (53–62)	67 (61–72)
Infant femur fracture	45 (38–52)	53 (49–58)	62 (56–67)	69 (61–78)

Predicted rates of evaluation for occult fractures at hospitals based on mean annual volume of encounters for patients <2 years old with diagnosis of traumatic injury. All models were adjusted for patient- and hospital-level covariates.

Covariates

Patient-level covariates included age (years), gender, race, insurance status (private versus government or no insurance), injury severity, and year of discharge. Previous studies have found that demographic characteristics and injury severity influence the likelihood of SSs.^{9,31} ICD-9-CM–based Abbreviated Injury Scores for the head and lower extremities were calculated for the infant TBI and femur groups, respectively, by using the ICDMAP-90 injury diagnosis software (John Hopkins University, Baltimore, MD, and Tri-Analytics, Inc, Ponte Vedra Beach, FL). Hospital-level covariates included geographic region (Northeast, Midwest, South, or West), hospital setting (urban or rural), teaching status (teaching or nonteaching), and the annual injury volume of patients <2 years old. Injury volume was created as a continuous variable on the basis of the number of patients <2 years old discharged from the hospitals each year with a diagnosis of an injury (ICD-9-CM codes 800–959).

Statistical Analysis

We calculated the unadjusted rate of occult fracture evaluation by hospital for each of the 3 study groups (abuse, infant TBI, and infant femur fracture). We used logistic regression models to estimate the association between patient-level (race, gender, insurance status, year of discharge) and hospital-level (geographic region, hospital setting, teaching status, and log-transformed [base 2] annual injury volume) variables with the odds of occult fracture evaluation for each of the 3 groups.³² For the infant TBI model, we also included the injury severity score for the head region as a patient-level covariate. Similarly, the infant femur model included the injury severity score for the lower extremity region. All models used a robust variance estimator to account for correlation due to clustering of children within hospitals.

We used a mixed-effects logistic regression model to quantify variability across hospitals in occult fracture evaluation in each of the 3 groups (abuse, infant TBI, and infant femur fracture) for each hospital after adjustment for patient case mix.³³ The model included patient-level variables as fixed effects and hospital-level random intercepts. We performed a separate analysis for each patient group and included the appropriate injury severity score. We limited our analysis to include only hospitals with at least 5 cases in the patient group. We calculated the predicted probabilities of SS by patient group. All analyses were completed in Stata 12.1 (StataCorp, College Station, TX).

RESULTS

Study Population

Our analytic sample of 4486 children were treated at 366 hospitals. The sample included 2502 children aged <2 years old diagnosed with physical abuse (Table 1). Of the 2433 infants identified as having a high-risk injury, 65% had TBIs and 35% had femur fractures. Only 3% (12) of the hospitals served a primarily pediatric population, defined as $\geq 75\%$ of non-birth-related encounters occurring in patients ≤ 18 years old.

Evaluation for Occult Fractures in Children Diagnosed With Physical Abuse

Forty-eight percent of the children diagnosed with physical abuse received evaluation for occult injuries. In multivariable analysis, age of <1 year was associated with higher odds of evaluation (Table 2). Among children diagnosed with physical abuse, the odds of evaluation for occult fracture varied by race, with black children having the lowest odds of undergoing evaluation. The odds of evaluation for occult fractures were higher at teaching hospitals than at nonteaching hospitals (Table 2). There were differences by

region, with the highest odds of evaluation occurring in the South. The annual volume of injured children cared for at the hospitals was associated with the likelihood of occult fracture evaluation such that hospitals with higher volumes of young, injured children were more likely to evaluate for occult fractures (Tables 2 and 3).

There were 112 hospitals with 2053 cases of diagnosed abuse available for inclusion in the analysis of variation across hospitals. The unadjusted rate of evaluation for occult fractures ranged from 0% to 100%. Even after adjusting for patient demographic characteristics and injury severity,

significant variation in evaluation rates across hospitals persisted, with rates ranging from 15% to 100% ($P < .001$; Fig 2).

Evaluation for Occult Fractures in Children Diagnosed With High-Risk Injuries

Occult injury evaluation was performed in 51% of the TBI group and 53% of the femur fracture group. Among infants with these high-risk injuries, abuse was diagnosed in 32% of those undergoing occult fracture evaluation. In multivariable analysis, government-sponsored insurance increased the odds of evaluation for both the TBI and the femur fracture

FIGURE 2

Variation in screening for occult fractures in children <2 years old diagnosed with physical abuse across 112 hospitals. Results were generated from a mixed-effects logistic regression model, adjusted for age, gender, insurance, and year of discharge. Point estimates for individual hospitals are plotted as well as a weighted scatterplot smoothing of the rate of occult fracture evaluation as a function of the log of the mean annual hospital volume of patients <2 years old.

FIGURE 3

Variation in screening for occult fractures in infants <1 year old with non-MVC-related TBI across 49 hospitals. Results were generated from a mixed-effects logistic regression model, adjusted for gender, insurance, year of discharge, and severity of TBI on the basis of the ICD-9-CM-based Abbreviated Injury Scores for the head region. Point estimates for individual hospitals are plotted as well as a weighted scatterplot smoothing of the rate of occult fracture evaluation as a function of the log of the mean annual hospital volume of patients <2 years old.

FIGURE 4

Variation in screening for occult fractures in infants <1 year old with non-MVC-related femur fractures across 43 hospitals. Results were generated from a mixed-effects logistic regression model, adjusted for gender, insurance, year of discharge, and severity of femur fracture on the basis of the ICD-9-CM-based Abbreviated Injury Scores for the lower extremity region. Point estimates for individual hospitals are plotted as well as a weighted scatterplot smoothing of the rate of occult fracture evaluation as a function of the log of the mean annual hospital volume of patients <2 years old.

groups (Table 2). In the TBI group, there was an association of race with occult fracture evaluation, with the highest odds of evaluation observed in infants with “other/unknown” race. Among infants with TBI or femur fracture, teaching hospitals and hospitals with a higher volume of injured, young children were associated with increased odds of evaluation for occult fractures (Tables 2 and 3).

There were 49 hospitals with 1361 cases of TBI available for inclusion in the analysis of variation across hospitals. Unadjusted rates of evaluation for occult fractures in infants with TBIs ranged from 0% to 90% across hospitals. There were 43 hospitals with 562 cases of femur fracture available for the inclusion in the analysis of variation across hospitals. Unadjusted rates of evaluation for occult fractures in infants with femur fractures ranged from 0% to 100% across hospitals. After adjusting for patient demographic characteristics and injury severity, we found significant variation in evaluation rates across hospitals ($P < .001$). For the infant TBI group, adjusted rates of evaluation ranged from 26% to 98% across hospitals (Fig 3). For the infant femur group, adjusted rates of evaluation ranged from 26% to 77% (Fig 4).

DISCUSSION

Just under half of the >2500 children aged <2 years old with an abuse diagnosis underwent evaluation for occult fractures, despite recommendations from the American Academy of Pediatrics that SSs should be universally performed in this population.^{7,8} On the basis of previous studies, ~25% to 30% of these children would be expected to have occult fractures revealed on SSs.^{2, 34} Thus, ~1 of every 7 or 8 children in our study sample may have had undiagnosed occult fractures. The rate of occult fracture evaluation among children with an abuse diagnosis in our study cohort, which primarily included non-pediatric-focused hospitals, was lower than the rate of 83% reported in a study of 40 pediatric hospitals.⁹ Further examination revealed that teaching status and greater experience with young, injured children, as measured by the annual hospital volume of patients <2 years old with an injury diagnosis, were associated with increased odds of occult fracture evaluation.

Only half of infants with non-MVC-related TBIs and femur fractures underwent occult fracture evaluation. An argument could be made that not all of these infants required occult fracture evaluations and that the

decision should be made on a case-by-case basis, taking into account the presenting history and other clinical factors not able to be captured in our study. We assert, however, that on the basis of the well-documented significant risk of abuse in infants with these injuries,^{10–16,35} a more standardized approach is needed. Over the past 25 years, research has repeatedly highlighted missed opportunities to evaluate and diagnose abuse in young, injured children, resulting in children suffering from undiagnosed injuries as well as ongoing abuse.^{36–43} Research has also revealed that racial and socioeconomic status (SES)-based biases influence decision-making regarding child abuse evaluations and diagnoses.^{17,31,35,44,45} A single institution study of unwitnessed TBI in infants showed that implementation of a guideline for universal occult fracture evaluation in this population can eliminate racial and SES-based disparities and might increase the detection of abuse.³⁵ Thus, the development and implementation of guidelines for occult fracture evaluation in young, injured children has the potential to not only address disparities in care but also to increase early detection of abusive injuries and protect children from further harm. In developing national guidelines, the benefits of increased detection of occult fractures will need to be balanced with the risks of increased exposure to radiation. The observed lack of adherence at some hospitals to the existing occult fracture evaluation guidelines for children diagnosed with abuse suggests, however, that simply developing guidelines for children with high-risk injuries will not be sufficient to change practice. Qualitative assessments of hospitals with high guideline adherence rates and hospitals with low adherence rates may be helpful in informing guideline implementation and quality improvement strategies. Formal

examination of the acceptability of developed guidelines by using tools such as The Ottawa Acceptability of Decision Rules Instrument will also be necessary.⁴⁶ Previous research has shown that computerized reminder and decision support systems, interactive educational meetings or outreach, guideline content, and multifaceted interventions are effective in guideline implementation.^{47,48}

In keeping with previous studies showing that lower SES is associated with increased rates of evaluation for and diagnosis of abuse, we found that government insurance was associated with increased odds of occult fracture evaluation in infants with high-risk injuries.^{35,43,45,48,49} In contrast to previous studies, however, we did not find a consistent relationship between minority race and increased rates of occult fracture evaluation in infants with high-risk injuries.^{31,35,43,49} In the group of children diagnosed with abuse, black race was associated with lower odds of occult fracture evaluation, suggesting that once a diagnosis of abuse is made, black children may receive a less thorough evaluation than white children. Our ability to study the association of race with occult fracture evaluation practices, however, was limited by the frequency of missing data for race in our cohort.

Our study has several limitations. First, the study relied on administrative data, which are subject to coding inaccuracies. Studies have raised concern about the sensitivity of ICD-9-CM and E-codes to identify abuse cases.^{49,50} Importantly, however, the reported specificity of the codes to identify cases of diagnosed physical abuse or abusive head trauma is high.^{49,51} Thus, although we may not have captured all cases of abuse for inclusion in our cohort, the risk of having inappropriately categorized accidental injuries as abusive is low. Incomplete use of E-codes might have resulted in MVC-related injuries not being fully excluded from our study cohort, which would overestimate the proportion of cases in which occult fracture evaluation could be considered appropriate. The magnitude of this effect would be small, however, because a minority of femur fractures and TBIs are attributed to MVCs in young children. MVC-related trauma accounts for 5% to 11% of femur fractures in children <3 years old and <10% of TBI hospitalizations in children <5 years old.^{13,52–54} Second, unobserved patient-level factors, including reported history of trauma and other clinical details, might have influenced the decision to obtain an SS and contributed to the observed variation. Third, the number of eligible cases seen at

some of the non-pediatric-focused hospitals was low, and as such the estimates at these hospitals are relatively unstable. Furthermore, children with more severe injuries may have been preferentially transferred to pediatric centers, biasing our sample toward children with less severe injuries. Finally, because of the nature of the administrative data, we are unable to determine the results of the occult fracture evaluation.

Despite these limitations, our results show a lack of uniform adherence to occult fracture evaluation recommendations in young victims of abuse. The marked variation in occult fracture evaluation rates among infants with high-risk injuries raises concerns for missed opportunities to detect abuse and protect children. These results highlight an opportunity to improve quality of care for this vulnerable population.

ABBREVIATIONS

ICD-9-CM: International Classification of Diseases, Ninth Revision, Clinical Modification
MVC: motor vehicle crash
SES: socioeconomic status
SS: skeletal survey
TBI: traumatic brain injury

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