

Clinical–Management Collaboration for Improving TBI Principal Diagnosis Coding: A Quasi-Experimental Quality Improvement Study

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Abstract

Background

Clinical coding in complex diseases depends on the accurate generation, interpretation, documentation, and translation of clinical information. Coding discrepancies may therefore arise across the clinical-information pathway rather than solely during final code assignment. This study examined whether implementation of a disease-specific quality improvement programme for TBI was accompanied by a differential change in principal diagnosis coding accuracy relative to a contemporaneous comparison group.

Methods

A single-centre, controlled quasi-experimental quality improvement study using a repeated cross-sectional design was conducted in a tertiary hospital in China. In January 2025, a FOCUS-PDCA programme integrating clinical documentation optimization, neuroimaging verification, clinical-to-classification mapping, and multidisciplinary quality control was implemented in the Department of Neurosurgery. The study included 400 patients: 200 TBI patients in the intervention group and 200 patients with nontraumatic intracranial haemorrhage in a contemporaneous comparison group, with 100 patients per group in each study year. Differential changes in principal diagnosis coding accuracy were evaluated using difference-in-differences analysis based on linear probability models (LPM-DID).

Results

Principal diagnosis coding accuracy increased from 53.0% to 74.0% in the TBI intervention group, while it changed from 89.0% to 86.0% in the contemporaneous comparison group. The adjusted LPM-DID estimate indicated a 22.2-percentage-point differential change in coding accuracy in the intervention group relative to the concurrent change in the comparison group (95% CI, 5.8–38.7 percentage points; $P = 0.008$). A logistic DID sensitivity analysis yielded findings consistent with the primary analysis.

Conclusions

The observed differential improvement in principal diagnosis coding accuracy was consistent with an information-pathway approach to coding quality management. The findings suggest that coding quality improvement in clinically complex diseases may benefit from extending quality control beyond final code review to multidisciplinary review across the clinical-information pathway. More reliable standardized coded information may improve the fitness of routinely collected hospital data for case-mix measurement, healthcare quality assessment, DRG/DIP-based management, and data-driven hospital management.

Background

Accurate clinical coding is essential for healthcare quality assessment, case-mix measurement, and prospective payment systems[1, 2]. In China, standardized diagnostic information recorded on medical record front pages provides a key data source for Diagnosis-Related Groups (DRGs) and Diagnosis-Intervention Packet (DIP) management, making coding reliability relevant not only to health information quality but also to downstream hospital management[3, 4, 5]. However, clinical coding represents the final stage of a broader information pathway spanning clinical evidence generation, imaging interpretation, clinical documentation, and classification mapping. In clinically complex diseases, coding discrepancies arise across this continuum rather than solely during code assignment. Incomplete documentation, non-standardized clinical terminology, and misalignment between imaging findings and ICD classification dimensions may undermine principal diagnosis selection[6]. Coding quality improvement may therefore need to address not only final code assignment but also upstream processes of clinical information generation, interpretation, documentation, and translation[7, 8].

Traumatic brain injury (TBI) provides a relevant model for examining coding quality in clinically complex conditions. Characterized by heterogeneous injury mechanisms and concurrent lesion patterns, TBI diagnosis and classification requires the integration of clinical manifestations, neurological findings, and neuroimaging (CT/MRI) evidence[9]. Information compression and dimensional conflation—such as misinterpreting severity terms or confusing diffuse injury with multiple focal injuries—may complicate principal diagnosis selection and standardized code assignment. Although previous studies have examined TBI case identification and coding validity, empirical evidence on how coding discrepancies arise across the clinical-information pathway remains limited[10, 11].

Existing quality improvement approaches are often generic and rely primarily on coder training or retrospective audits, with limited ability to address information loss or misalignment arising upstream. Furthermore, intervention studies frequently employ simple before-and-after designs, which are vulnerable to secular trends and concurrent institutional changes[12]. Based on this information-pathway perspective, we hypothesized that strengthening cross-disciplinary information review across the clinical-information pathway could improve the reliability of principal diagnosis coding. To operationalize this approach, a disease-specific quality-improvement programme based on the FOCUS-PDCA framework was implemented for patients with TBI in the Department of Neurosurgery. The programme integrated clinical documentation optimization, neuroimaging verification, clinical-to-classification mapping, and multidisciplinary quality control[13]. Using a contemporaneous comparison group and a difference-in-differences (DID) quasi-experimental design, this study evaluated differential changes in principal diagnosis coding accuracy following programme implementation and examined the implications for information-pathway-based coding quality management[14].

Materials and Methods

Study design

This was a single-centre, controlled quasi-experimental quality improvement study using a repeated cross-sectional design. In January 2025, a FOCUS-PDCA quality-improvement programme targeting the clinical-information pathway underlying medical record front-page coding was implemented for TBI in the Department of Neurosurgery[15, 16]. A contemporaneous comparison group of inpatients with nontraumatic intracranial haemorrhage from the Department of Neurology continued to receive routine hospital-level medical record front-page quality control but did not participate in the FOCUS-PDCA programme. Pre-intervention (2024) and post-intervention (2025) periods were compared between the two groups, with principal diagnosis coding accuracy on the medical record front page serving as the primary outcome for evaluating differential changes following programme implementation[17]. This study was reported in accordance with the Standards for Quality Improvement Reporting Excellence (SQUIRE 2.0) guidelines; the completed SQUIRE 2.0 checklist is provided in Supplementary Table S1. The study protocol was approved by the Ethics Committee of the Hanzhong Central Hospital (Review No. 140, 2026; Date: 13 August 2026) and conducted in accordance with the principles of the Declaration of Helsinki. Due to the retrospective design and use of anonymized data, the requirement for informed consent was waived.

Context

Before implementation of the programme, routine medical record quality control was primarily conducted after patient discharge and medical record completion. Relevant departments performed quality-control activities largely within their own responsibilities, including review of medical record completeness, documentation requirements, diagnostic completeness, medical record front-page coding, and insurance-related requirements. Although clinicians, neuroradiologists, medical coders, and insurance administrators contributed to different stages of the clinical-information pathway, quality-control activities were largely department-based, with limited structured verification of information across these stages. Problems identified during downstream medical record or insurance review were generally fed back to the relevant clinical departments after record completion. This fragmented and predominantly retrospective workflow provided the context for introducing FOCUS-PDCA to move quality control upstream by establishing cross-departmental verification of clinical information before medical record front-page coding, thereby improving the information basis for accurate principal diagnosis selection and code assignment.

Data source and study population

Data source and sampling strategy

Data were retrieved from the electronic medical record (EMR) system and medical record front-page database of a tertiary grade-A general hospital in China for patients discharged between January 1, 2024, and December 31, 2025. Extracted variables included demographic characteristics, principal and

secondary ICD-10 diagnoses, surgical and interventional procedures, admission route, disease severity, duration of invasive mechanical ventilation, and discharge status.

Eligible records were identified separately for each study group and calendar year. Simple random sampling was performed within each group-year stratum, selecting 100 patients per stratum. The final study sample comprised 400 patients: 200 from the pre-intervention period (100 TBI, 100 nontraumatic intracranial haemorrhage) and 200 from the post-intervention period (100 TBI, 100 nontraumatic intracranial haemorrhage).

Eligibility criteria

Patients were eligible if they met the prespecified diagnostic and neuroimaging criteria for either study group. For the neurosurgery group, the principal diagnosis recorded on the medical record front page was required to fall within traumatic intracranial injury (ICD-10: S06), with CT or MRI confirming the presence of an intracranial haematoma. For the neurology comparison group, the principal diagnosis was required to fall within nontraumatic intracranial haemorrhage (ICD-10: I60–I62), with corresponding clinical and neuroimaging evidence supporting the diagnosis. Complete data were required for all study covariates.

Patients were excluded if: (1) the principal diagnosis code fell outside the prespecified S06 or I60–I62 categories; (2) clinical documentation or neuroimaging findings did not support the corresponding diagnostic category; (3) no intracranial haematoma was identified on neuroimaging in the TBI group; or (4) key demographic, clinical, or medical record variables required for analysis were missing.

The study evaluated the accuracy of principal diagnosis selection and code assignment among patients meeting these prespecified diagnostic and neuroimaging criteria; potentially miscoded cases outside the S06 or I60–I62 categories were not evaluated.

Disease-specific FOCUS-PDCA intervention

A disease-specific clinical coding quality improvement programme based on the FOCUS-PDCA framework was implemented in the Department of Neurosurgery in January 2025. The FOCUS framework was used to identify discrepancies and their underlying causes along the clinical-information pathway, and subsequent PDCA cycles translated these findings into targeted improvement measures. Pre-intervention audits and root-cause analyses identified recurrent problems involving incomplete clinical documentation, ambiguity in neuroimaging interpretation or documentation, inconsistent understanding of ICD classification dimensions, and fragmented interdisciplinary communication. Based on these findings, a multidisciplinary team (MDT)—comprising neurosurgeons, neuroradiologists, medical coders, quality managers, and healthcare insurance administrators—implemented three interrelated intervention modules.

Clinical information and documentation optimization was carried out by putting mandatory documentation rules into clinical EMR workflows, so progress notes and front-page records were required to clearly record anatomical sites, injury patterns, consciousness status, and related neuroimaging findings. For cases where clinical terms were unclear or neuroimaging evidence was not enough, neurosurgeons and neuroradiologists performed joint pre-submission reviews before final coding, in order to clarify the diagnostic information.

Clinical-to-classification mapping and decision support were strengthened by adding disease-specific audit and alert rules that matched ICD-10 classification logic into the Intelligent Medical Coding System. When predefined high-risk codes were selected, including S06.2 (diffuse traumatic brain injury), S06.3 (focal traumatic brain injury), and S06.7 (intracranial injury with prolonged coma), automated prompts were triggered, and coders were asked to re-check relevant progress notes and neuroimaging reports before final code assignment; in this way, consistency between source clinical information and standardized classification was improved.

Multidisciplinary audit, targeted training, and feedback governance were set up through the MDT development of a standardized operational manual named Guideline for TBI Principal Diagnosis Selection and Coding Compliance; targeted training was also provided to junior neurosurgeons and surgical residents, so clinical documentation and ICD classification logic could be better aligned at the point of care. Health record managers and insurance administrators also used coding-related problems found during DRG/DIP review as additional signals for case review, and feedback was sent to clinical departments. Parts of the intervention that still needed improvement were adjusted through later PDCA cycles within the Department of Neurosurgery, while practices that showed stable applicability were made standard and shared with other clinical departments through targeted training and quality-improvement activities.

Outcome measures

The primary outcome was principal diagnosis coding accuracy on the medical record front page, evaluated as a binary variable (1 = correct, 0 = incorrect). Coding accuracy was reviewed by two senior medical coders based on the documented principal diagnosis, complete EMR documentation, formal neuroimaging reports (CT/MRI), and applicable ICD-10 coding rules, in accordance with the National Guidelines for Front-Page Medical Record Quality Management and Clinical Coding in China. A case was considered correctly coded when both the principal diagnosis selection and the corresponding ICD-10 code assignment were consistent with the supporting clinical and neuroimaging evidence and applicable coding rules. Disagreements between the two reviewers were resolved through secondary review by a senior neurosurgeon and a chief medical record specialist. For incorrectly coded TBI cases, discrepancy patterns were further categorized based on the coding audit findings.

Covariates

Six prespecified patient-level covariates were included to adjust for potential differences in case-mix and clinical complexity. Demographic variables included age (continuous, years) and sex (binary, male vs. female). Baseline clinical severity was captured by admission route (binary, emergency vs. non-emergency) and disease severity at admission (categorical: critical, urgent, or general). Treatment intensity included surgical intervention (binary, yes vs. no) and prolonged invasive mechanical ventilation duration (> 96 hours, binary, yes vs. no). Operational definitions and coding specifications are summarized in Table 1.

Table 1
Variable definitions and operational assignments

Variable Class	Variable Name	Type	Operational Definition Assignment	Data Source
Primary Outcome	Principal diagnosis accuracy	Binary	1 = Correct;0 = Incorrect	Expert audit
Independent Variables	Group (treat)	Binary	1 = Neurosurgery group (TBI); 0 = Neurology nontraumatic intracranial haemorrhage group	Front-page
	Time period (post)	Binary	1 = Post-intervention (2025); 0 = Pre-intervention (2024)	Front-page
	Interaction term (did)	Binary	Interaction term: treat × post	Calculated
Demographic Factors	Age	Continuous	Patient age in completed years	Front-page
	Sex	Binary	1 = Male; 0 = Female	Front-page
Clinical Severity	Admission route	Binary	1 = Emergency; 0 = Non-emergency	Front-page
	Disease severity at admission	Categorical	1 = Critical; 2 = Urgent; 3 = General	Front-page
Treatment Intensity	Surgical intervention	Binary	1 = Yes (received surgery/procedure); 0 = No	Front-page
	Mechanical ventilation > 96h	Binary	1 = Yes; 0 = No	Front-page

Statistical analysis

Continuous variables were summarized as medians with interquartile ranges (IQRs), and differences across the four study cells were assessed using the Kruskal–Wallis test because of their non-normal

distributions. Categorical variables were presented as frequencies and percentages and compared across the four study cells using Pearson's chi-square (χ^2) test.

Changes in principal diagnosis coding accuracy were evaluated using a difference-in-differences approach based on linear probability models (LPM-DID). Patients with TBI constituted the intervention group ($\text{treat} = 1$), and patients with nontraumatic intracranial haemorrhage constituted the contemporaneous comparison group ($\text{treat} = 0$); 2025 was defined as the post-intervention period ($\text{post} = 1$) and 2024 as the pre-intervention period ($\text{post} = 0$). Model 1 included treat , post , and their interaction term ($\text{treat} \times \text{post}$). Model 2 additionally adjusted for six prespecified covariates: age, sex, admission route, disease severity at admission, surgical intervention, and invasive mechanical ventilation > 96 hours.

The adjusted model was specified as:

$$Y_i = \beta_0 + \beta_1 \cdot \text{treat}_i + \beta_2 \cdot \text{post}_i + \beta_3 \cdot (\text{treat}_i \times \text{post}_i) + \sum_{k=1}^6 \gamma_k \cdot X_{ki} + \varepsilon_i$$

where Y_i denotes principal diagnosis coding accuracy (1 = correct, 0 = incorrect), treat_i represents group membership, post_i represents the post-intervention period, and X_{ki} represents the vector of the six prespecified covariates. The interaction coefficient β_3 was the primary DID estimator, representing the differential pre-to-post change in principal diagnosis coding accuracy in the intervention group relative to the concurrent change in the comparison group. ε_i denotes the error term.

Because only one pre-intervention year was available, the parallel-trends assumption could not be empirically assessed using multiple pre-intervention periods. Therefore, the DID framework was used to quantify the group-by-period differential change in principal diagnosis coding accuracy rather than to establish a definitive causal effect of the programme. As a sensitivity analysis, a multivariable logistic regression model with the same DID specification and covariates was fitted to assess the robustness of the findings to an alternative model specification for the binary outcome. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs). All analyses were performed using Python version 3.7, with two-sided $P < 0.05$ considered statistically significant.

Results

Characteristics of the study population

A total of 400 patients were included, comprising 200 patients in the intervention group and 200 in the contemporaneous comparison group, with 100 patients from each group in both 2024 and 2025. Patient characteristics across the four study cells are presented in Table 2. Overall comparisons across the four study cells indicated differences in age, sex, disease severity at admission, surgical intervention, and invasive mechanical ventilation > 96 h (all $P < 0.05$), whereas no overall difference was observed in emergency admission ($P = 0.492$).

Table 2
Characteristics of the study population by study group and period

Characteristic	Intervention 2024 (n = 100)	Intervention 2025 (n = 100)	Control 2024 (n = 100)	Control 2025 (n = 100)	P value
Age, median (IQR)	60 (50–72)	58 (46–68)	66 (54–72)	62 (54–73)	0.016
Male sex, <i>n</i> (%)	55 (55.0)	71 (71.0)	63 (63.0)	54 (54.0)	0.048
Emergency admission, <i>n</i> (%)	86 (86.0)	84 (84.0)	79 (79.0)	86 (86.0)	0.492
Critically ill at admission, <i>n</i> (%)	50 (50.0)	59 (59.0)	72 (72.0)	77 (77.0)	< 0.001
Surgical treatment, <i>n</i> (%)	18 (18.0)	28 (28.0)	33 (33.0)	39 (39.0)	0.010
Invasive mechanical ventilation > 96 h, <i>n</i> (%)	8 (8.0)	13 (13)	5 (5.0)	3 (3.0)	0.038

Changes in principal diagnosis coding accuracy

Principal diagnosis coding accuracy in the intervention group increased from 53.0% in 2024 to 74.0% in 2025, an absolute increase of 21.0 percentage points. In the contemporaneous comparison group, coding accuracy changed from 89.0% to 86.0%, corresponding to a decrease of 3.0 percentage points (Table 3).

Table 3
Principal diagnosis coding accuracy by study group and study period

Group	2024, %	2025, %	Absolute change, percentage points
Intervention	53.0	74.0	+ 21.0
Control	89.0	86.0	–3.0

Difference-in-differences analysis

In the unadjusted DID model, the coefficient for the treat × post interaction was 0.240 (95% CI, 0.079–0.401; *P* = 0.003), indicating a 24.0-percentage-point differential change in principal diagnosis coding accuracy in the intervention group relative to the concurrent change in the comparison group.

After adjustment for age, sex, admission route, disease severity at admission, surgical intervention, and invasive mechanical ventilation > 96 h, the DID estimate was 0.222 (95% CI 0.058–0.387; *P* = 0.008), corresponding to an adjusted differential change of 22.2 percentage points relative to the

contemporaneous comparison group. The estimate was similar in direction and magnitude to the unadjusted result (Table 4).

Table 4
Difference-in-differences estimates of changes in principal diagnosis coding accuracy

Model	DID interaction estimate, β	95% CI	P value
Unadjusted DID model	0.240	0.079–0.401	0.003
Adjusted DID model [ⓧ]	0.222	0.058–0.387	0.008
[ⓧ] Adjusted for age, sex, route of admission, severity of condition at admission, surgical treatment, and invasive mechanical ventilation for > 96 h.			

Sensitivity analysis

The logistic DID sensitivity analysis yielded an association in the same direction as the primary LPM analysis. The treat×post interaction was statistically significant in both the unadjusted model (OR 3.32, 95% CI 1.19–9.31; P = 0.022) and the adjusted model (OR 3.01, 95% CI 1.12–8.09; P = 0.029) (Table 5).

Table 5
Sensitivity analysis using logistic difference-in-differences models

Model	Interaction coefficient, β	OR for treat × post	95% CI	P value
Unadjusted logistic DID model	1.201	3.32	1.19–9.31	0.022
Adjusted logistic DID model	1.102	3.01	1.12–8.09	0.029

Patterns of principal diagnosis coding discrepancies

Among the 100 TBI cases reviewed in 2024, 47 principal diagnosis coding errors were identified. S06.2/S06.3 classification discrepancies accounted for the largest proportion, occurring in 28 cases (28.0% of all TBI cases), followed by other discrepancies in 12 cases (12.0%) and S06.7-related discrepancies in 7 cases (7.0%). In 2025, 26 coding errors were identified among 100 TBI cases, including 19 S06.2/S06.3 classification discrepancies (19.0%), 6 other discrepancies (6.0%), and 1 S06.7-related discrepancy (1.0%) (Table 6).

Table 6
Patterns of principal diagnosis coding discrepancies in the TBI group

Discrepancy pattern	2024, n (%)	2025, n (%)
S06.7-related discrepancy	7 (7.0)	1 (1.0)
S06.2/S06.3 classification discrepancy	28 (28.0)	19 (19.0)
Other discrepancies	12 (12.0)	6 (6.0)
Total coding errors	47 (47.0)	26 (26.0)
Percentages were calculated using all TBI cases in each study period (n = 100) as the denominator. Discrepancy categories were mutually exclusive.		

Discussion

Disease-specific coding discrepancies and classification challenges in TBI

S06.2 and S06.3: classification boundaries and information granularity

S06.2/S06.3 classification discrepancies were the predominant error pattern in the TBI group, decreasing from 28.0% before the intervention to 19.0% after implementation. A central difficulty was distinguishing multiple focal injuries from diffuse brain injury. “Multiple” describes the number or spatial distribution of lesions, whereas “diffuse” represents a distinct injury pattern[18, 19, 20]. Multiple anatomically discrete contusions or haematomas should therefore not be classified as diffuse injury solely because more than one lesion is present. Accurate distinction requires integrated assessment of injury characteristics and neuroimaging findings by clinicians and neuroradiologists and cannot be resolved by coding rules alone[21, 22].

A separate challenge concerns the ability of standardized classifications to preserve clinically specific information. Under ICD-10, S06.3 identifies focal brain injury but has limited capacity to represent detailed anatomical sites or the distribution of multiple focal lesions, resulting in information compression when clinically heterogeneous injuries are translated into coded data[23]. ICD-11 provides more differentiated representation of traumatic intracranial injuries and haemorrhage types, with post-coordination and extension codes allowing additional clinical attributes to be represented[24]. This greater granularity may narrow the gap between clinical diagnosis and standardized classification and provide more informative coded data for subsequent case-mix measurement, quality assessment, and data-driven management.

S06.7: discrepancies arising from different classification dimensions

S06.7-related discrepancies decreased from 7.0% before the intervention to 1.0% after implementation. Unlike S06.2–S06.6, which primarily characterize intracranial injuries according to injury pattern or anatomical–pathological type, S06.7 incorporates prolonged impairment of consciousness and therefore introduces a different classification dimension. Accordingly, its assessment depends primarily on longitudinal clinical documentation of consciousness status and duration rather than neuroimaging evidence. This difference in evidentiary basis may increase the risk of conflating the pathological type of injury with the patient’s clinical state during principal diagnosis selection and code assignment.

In practice, descriptors such as “severe TBI” or prolonged unconsciousness characterize clinical severity or consciousness status but do not necessarily identify the underlying pathological injury[25]. When a specific intracranial lesion has been established, the injury type and the associated consciousness status should therefore be distinguished rather than treated as interchangeable diagnostic dimensions. ICD-11 provides a more differentiated framework for representing intracranial injuries and associated clinical attributes, allowing pathological injury and consciousness-related information to be represented more distinctly. This evolution may improve alignment between clinical information and standardized classification by preserving clinically meaningful dimensions that are more easily conflated within ICD-10[26, 27].

Taken together, these discrepancies reflect a broader challenge in translating multidimensional clinical information into standardized diagnostic classifications. Although the specific error patterns were identified in TBI, the underlying problem arises at the interface between clinical interpretation and ICD-based classification rather than from institution-specific administrative processes alone.

From retrospective coding review to multidisciplinary upstream quality control

The findings support a shift in coding quality management from retrospective, coding-department-centred review toward multidisciplinary quality control embedded earlier in the clinical-information pathway. In conventional practice, coding discrepancies are often identified after medical records have been completed and submitted for coding, leaving limited opportunity to correct ambiguities or information gaps originating during clinical diagnosis and documentation[28, 29]. In this study, FOCUS-PDCA extended quality control upstream by involving clinicians, neuroradiologists, coders, and health information professionals before final code assignment. Clinical documentation, neuroimaging evidence, diagnostic formulation, and high-risk code selection were therefore reviewed at the stages where the information required for accurate coding was generated and interpreted. Following implementation, principal diagnosis coding accuracy increased by 21.0 percentage points in the TBI group, while decreasing by 3.0 percentage points in the contemporaneous comparison group; the adjusted DID estimate indicated a 22.2-percentage-point differential improvement.(95% CI: 5.8–38.7; P = 0.008)

This approach is particularly relevant to clinically complex diseases such as TBI, where coding errors often originate from incomplete clinical documentation or inconsistent diagnostic interpretation rather than the coding process itself. Our findings demonstrate that principal diagnosis accuracy functions as a

critical nexus connecting upstream clinical documentation with downstream health information utilization. By establishing structured diagnostic templates and multidisciplinary consensus across the clinical-information pathway, the FOCUS-PDCA framework bridges the translation gap between neuroimaging findings and standardized codes[30]. This shifts coding quality management from passive, end-stage error detection toward proactive upstream prevention, ultimately enhancing overall data quality and information governance capacity.

Implications for clinical coding and health information quality governance

Principal diagnosis coding quality should be considered not only a technical issue of medical record coding but also an integral component of hospital health information quality governance. Coded front-page data originate from clinical diagnosis and documentation and subsequently support disease statistics, healthcare quality assessment, case-mix measurement, and hospital management. Improving the accuracy and consistency of information before final code assignment may therefore enhance not only coding reliability but also the quality of standardized data generated from routine clinical care[31, 32].

This perspective aligns with the transition toward quality-oriented, data-driven hospital management. Inaccuracies in principal diagnosis selection or code assignment may propagate downstream into DRG/DIP classification and score deviations, thereby affecting the reliability of case-mix and payment-related information. As many coding discrepancies originate from upstream clinical documentation and diagnostic interpretation, the FOCUS-PDCA framework addresses these errors at their source through structured documentation and multidisciplinary quality control. By linking clinical documentation, diagnostic interpretation, principal diagnosis selection, and final code assignment, this upstream approach may improve the reliability of routinely collected hospital data and provide a transferable framework for strengthening information quality across the clinical-to-coding pathway in other ICD-based healthcare systems.

Strengths and limitations

This study has several strengths. The use of a contemporaneous comparison group and a DID design provided greater control for shared temporal changes than a simple pre–post comparison, with similar estimates observed after covariate adjustment and in the logistic sensitivity analysis. More importantly, the disease-specific FOCUS-PDCA programme was developed from a root-cause analysis of TBI coding discrepancies and extended coding quality control from retrospective, coding-department-centred review to multidisciplinary upstream processes involving clinical documentation, neuroimaging assessment, diagnostic formulation, and code assignment. This provided an operational approach to quality improvement across the clinical-information pathway.

Several limitations should be acknowledged. First, as a single-centre quality improvement initiative, the primary purpose of employing a DID design was to account for shared temporal trends rather than to

establish strict econometric causality. The observed difference-in-differences highlights a substantial, practical improvement in principal diagnosis coding accuracy under the multidisciplinary quality control model. Third, because the sampling framework was based on prespecified diagnostic categories, potentially eligible cases coded outside these categories were not captured. Finally, the multicomponent nature of the FOCUS-PDCA programme precluded isolation of the contribution of individual components, and its longer-term sustainability and downstream management effects require further evaluation. Nevertheless, the present findings support the potential usefulness of an information-pathway-oriented approach that extends coding quality management beyond final code review toward multidisciplinary upstream quality control in clinically complex diseases.

Abbreviations

CT

Computed Tomography

DID

Difference-in-Differences

DIP

Diagnosis-Intervention Packet

DRG

Diagnosis-Related Group

EMR

Electronic Medical Record

FOCUS-PDCA

Find–Organize–Clarify–Understand–Select–Plan–Do–Check–Act

GCS

Glasgow Coma Scale

ICD-10

International Classification of Diseases, 10th Revision

ICD-11

International Classification of Diseases, 11th Revision

ICH

Intracerebral Hemorrhage

MDT

Multidisciplinary Team

MRI

Magnetic Resonance Imaging

TBI

Traumatic Brain Injury

Declarations

Ethics approval and consent to participate:

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Hanzhong Central Hospital (Review No. 140, 2026; 13 August 2026). The requirement for individual informed consent to participate was waived by the Ethics Committee of Hanzhong Central Hospital because of the retrospective nature of the study and the use of anonymized routinely collected medical record data.

Consent for publication:

Not applicable.

Competing Interests:

The authors declare no conflicts of interest.

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Author Contribution

Conceptualization, Liting Su, Han Tang, and Yiling Li; methodology, Liting Su and Yiling Li; investigation, Liting Su; writing—original draft preparation, Liting Su and Han Tang; writing—review and editing, Liting Su and Hongwei Yang; visualization, Yiling Li. All authors have read and agreed to the published version of the manuscript.

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During the preparation of this manuscript, the authors used ChatGPT (OpenAI) and Gemini (Google) for language refinement and assistance with improving the clarity and readability of the manuscript. The authors reviewed and edited all AI-assisted output and take full responsibility for the content of this publication.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available because of patient privacy and Ethics Committee requirements. De-identified data may be available from the

corresponding author upon reasonable request and subject to approval by the Ethics Committee of Hanzhong Central Hospital.

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