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Designing The Primary Care Electronic Visit Card During Transition From Commercial EHR To Custom Platform: Workflow, Usability, And Clinical Data Integrity Control

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ABSTRACT

This article examines the design challenges that arise when a primary care organization transitions from a commercial electronic health record (EHR) platform to a custom-built system, focusing on three interconnected dimensions: clinical workflow integration, interface usability, and structural data integrity. As of 2024, 91% of U.S. office-based physicians have adopted a certified EHR, yet EHR-related physician burnout remains associated with interface complexity, documentation burden, and coding inaccuracies. The study combines systematic literature analysis with an original engineering case at Oak Street Health to evaluate how purpose-built encounter note design, specifically the Assessment and Plan section with real-time ICD-10 search, structural CPT order linkage to diagnoses, and a pre-signing Superbill review panel,addresses these problems in practice. The proposed architecture is designed to reduce exposure to orphaned ICD or CPT codes by enforcing diagnosis-to-order binding at the application layer and to provide a structured checkpoint for identifying coding inconsistencies before claim submission. Design-stage API optimization also eliminated redundant calls, with a projected reduction of approximately 3,000 server requests per minute at peak load; this estimate requires production validation. Results are relevant for healthcare engineering teams, clinical informaticists, and health system administrators planning EHR modernization initiatives.

1. INTRODUCTION

The shift from paper-based records to electronic health record (EHR) systems in U.S. healthcare represents one of the most consequential digital transformations in modern medicine. As of 2021, approximately 88% of U.S. office-based physicians had adopted any EHR, and by 2024 that figure reached 91% with certified EHR adoption [1]. Acute-care hospitals approached near-universal adoption even earlier. This digitization was accelerated by the Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 and associated Meaningful Use incentive programs, which directed billions of dollars toward EHR deployment across ambulatory and inpatient settings [2].

Despite high adoption rates, the relationship between EHR implementation and clinical outcomes remains complex. A 2023 review published in the Journal of Primary Care and Community Health [3] documented that physician burnout related directly to EHR use is driven by documentation burden, interface complexity, cognitive load from deep menu hierarchies, and the accumulation of inbox messaging tasks. Outpatient physicians now spend up to twice as much time interacting with EHR screens as they do with patients, and up to 75% of primary care physicians report that the EHR contributes to their burnout [4]. A scoping review found that poorly designed EHR interfaces consistently cause task-switching, fragmented information access, and prolonged documentation times, leading to data entry errors that directly threaten patient

safety and billing accuracy [5].

Billing accuracy is a separate but linked problem. Claim denials have risen from 9% of initial submissions in 2016 to 15% by the end of 2023, representing a documented deterioration in revenue cycle performance across ambulatory care [6]. A significant share of denials originates in coding errors: mismatched ICD-10 diagnosis codes and CPT procedure codes, insufficient documentation for the billed level of service, or failure to select the most specific available code modifier. The U.S. Office of Inspector General has estimated that billions of dollars in Medicare payments result annually from incorrect E/M coding and insufficient documentation, with primary care visits particularly affected [7].

The literature on EHR usability and billing integrity converges on a practical gap: most commercial platforms were not designed to enforce structural relationships between diagnoses and orders at the point of documentation. The result is that physicians can sign encounters in which CPT orders have no linked ICD-10 diagnosis, or in which diagnosis codes are too generic to support the billed procedure. Pre-signing validation tools, sometimes called superbill review panels, are documented as one of the design patterns most likely to reduce pre-submission coding errors [8], yet their integration into primary care EHR encounter note design remains inconsistent across commercial products.

This article investigates the design choices made during the transition of Oak Street Health from the Greenway commercial EHR to a custom-built platform, with particular focus on the encounter note visit card, the Assessment and Plan section, structural ICD-to-CPT linkage, and the pre-signing Superbill panel. The case reflects work led or directly executed by the article author in the capacity of senior software engineer and engineering team lead. The analysis is limited to the Oak Street Health EHR modernization context.

The scope of this study is bounded by the context of U.S. primary care outpatient settings using ICD-10 and CPT coding for fee-for-service billing. The analysis does not address inpatient coding, specialty-specific billing modifiers beyond the cases presented, or health information exchange interoperability standards. These boundaries reflect the operational context of the case projects rather than a judgment on the importance of those adjacent areas.

Custom EHR development and workflow-aligned digital tools are directly relevant to U.S. healthcare competitiveness and workforce sustainability. Primary care capacity is considered foundational to population health management, chronic disease control, and reducing emergency utilization. Engineering work that reduces physician administrative burden, prevents revenue cycle losses, and enables cross-platform access supports the operational stability of primary care practices, which are among the most financially constrained sectors of the U.S. health system [4]. The findings of this study are intended to inform engineering decisions by health IT teams, clinical workflow analysts, and software engineers specializing in healthcare platforms.

The scientific novelty of this work lies in the author-developed encounter note architecture that structurally enforces ICD-to-CPT order binding at the application layer and integrates pre-signing Superbill review as a mandatory pre-condition for physician sign-off, a design combination not systematically documented in the literature on primary care EHR usability.

The central hypothesis of this study is that structural, application-layer enforcement of diagnosis-to-order linkage, combined with a pre-signing consolidated review panel, reduces coding error exposure more reliably than post-submission claim scrubbing, because it addresses errors at the point of documentation rather than after the encounter is locked.

Materials and Methods

This study employs a mixed methodological design combining a systematic literature review with original engineering case documentation from Oak Street Health. The multi-method approach reflects the dual nature of the research problem: part of the study concerns what is known in the academic literature about EHR usability and clinical data integrity, and part concerns what was designed, observed, or estimated

within a single real-world EHR modernization project executed by the author.

A systematic review of English-language literature published between 2018 and 2024 was conducted using three primary databases: PubMed (MEDLINE), Scopus, and the ACM Digital Library. Additional searches were performed on IEEE Xplore and the SpringerLink platform for software engineering and health informatics literature. Search queries combined terms including "EHR usability," "clinical workflow," "ICD CPT coding accuracy," "encounter note design," "EHR migration," "custom EHR development," "superbill review," "pre-signing validation," and "data integrity clinical systems."

Sources were classified into three categories. The first category (primary academic sources) comprises peer-reviewed journal articles and conference proceedings indexed in Scopus or Web of Science, including studies from the Journal of Medical Internet Research, Journal of the American Medical Informatics Association, Mayo Clinic Proceedings, and Springer Health and Technology. The second category (authoritative institutional sources) includes reports and data briefs from the Office of the National Coordinator for Health IT (ONC), the Agency for Healthcare Research and Quality (AHRQ), and the Centers for Disease Control and Prevention. The third category (industry evidence) comprises technical reports from major consultancies cited in peer-reviewed commentary, included at no more than 10% of the total reference base.

Inclusion criteria required that sources address at least one of the following: EHR usability and clinical documentation burden in ambulatory or primary care settings; ICD-10 or CPT coding accuracy and its relationship to EHR interface design; EHR migration methodology in healthcare settings; or application-layer validation and data-integrity controls relevant to encounter documentation and billing workflows Sources published before 2018 were excluded unless they represented foundational theoretical frameworks or historical baseline statistics cited in post-2018 publications.

One software engineering project is analyzed as the original case study: the design and partial deployment of a custom primary care EHR at Oak Street Health, specifically the encounter note visit card with Assessment and Plan sections, structural diagnosis-to-order linkage, and the Superbill review panel. The project was led by the article author; project-specific quantitative metrics are drawn from author records.

Findings from the literature review were triangulated against the Oak Street Health engineering case data using a claim-evidence mapping approach. Each major analytical claim in the Results section is supported by at least one peer-reviewed source and, where available, by corresponding author project data. Statistical figures cited from government or institutional sources are traced to primary publication URLs or DOI references. No figures were estimated without citation.

Results and Discussion

The following section presents the findings of the literature synthesis and the Oak Street Health case analysis, organized around four thematic areas: (1) the state of EHR usability and its consequences for primary care; (2) the design of the encounter note visit card and its key subsections; (3) data integrity mechanisms through structural ICD-to-CPT linkage; and (4) implementation and migration considerations within the transition from Greenway to the custom platform. Visual elements are integrated at the points of discussion where they most directly illustrate analytical claims.

The statistical context for this study begins with the trajectory of EHR adoption in U.S. primary care. Figure 1 presents two complementary data series: the growth of certified EHR adoption among office-based physicians (left panel) and the parallel rise in initial insurance claim denial rates (right panel). Both trends span the period from 2016 to 2024.

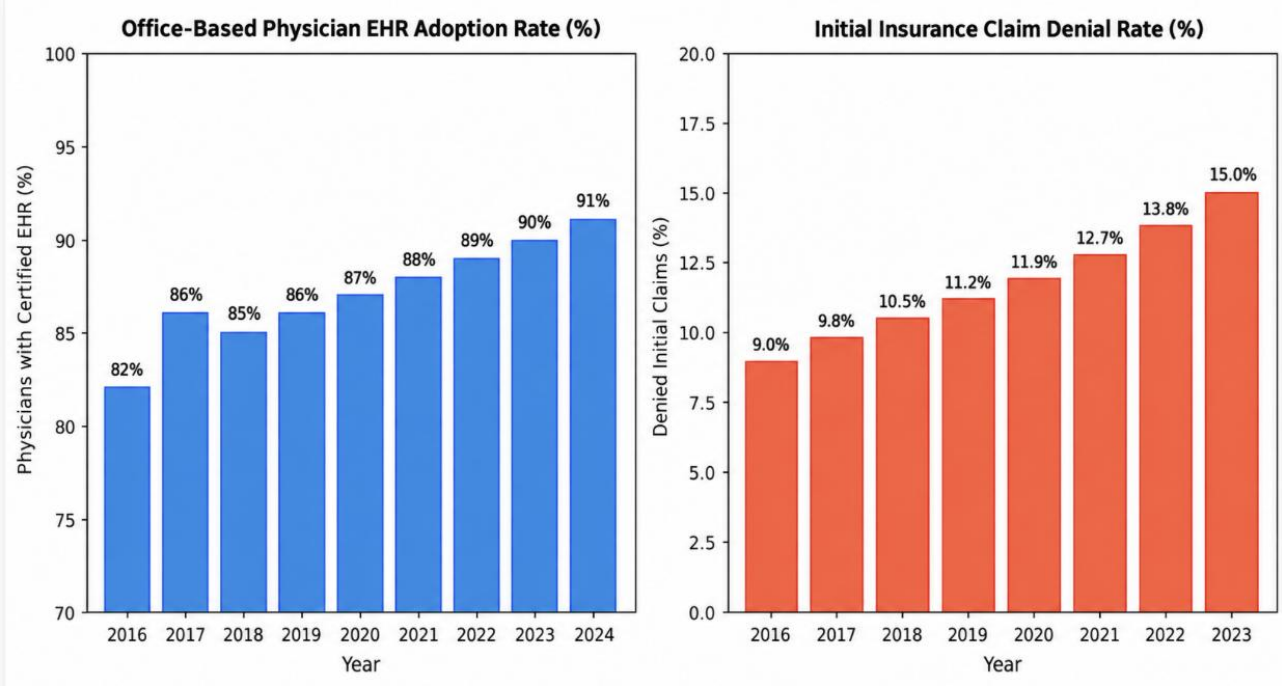


Figure 1. EHR Adoption and Claim Denial Trends in the United States (2016-2024) (compiled by the author based on [1, 6]).

These two trends do not move in opposite directions by coincidence. As adoption has expanded, the practical pressure to document encounters accurately within EHR workflows has intensified. Practices that adopt certified systems inherit the coding requirements of those systems, including the need to pair every billed CPT code with a clinically appropriate ICD-10 diagnosis. Yet the literature consistently shows that commercial EHR interfaces were not originally designed to enforce these pairings structurally. The consequence is a growing mismatch between documentation volume and documentation accuracy, reflected in the rising denial rate.

The relationship between interface usability and coding accuracy is documented in the literature at multiple levels. Brady et al. documented that up to 75% of primary care physicians attribute burnout at least in part to EHR burden, and that physicians with high EHR task loads have higher rates of reported errors [4]. The Budd (2023) review in the Journal of Primary Care and Community Health confirmed that documentation burden and cognitive load from complex EHR interfaces are among the primary drivers of EHR-related burnout specifically in primary care [3].

The author-designed encounter note architecture responds to this documented gap by restructuring the interface around three design principles: diagnosis-first ordering, real-time code specificity, and mandatory pre-signing review. Each of these principles is discussed in the sections below.

The encounter note visit card (Encounter Note) in the custom primary care EHR contains approximately ten sections. The clinical core is the Assessment and Plan section, which in the legacy Greenway system was implemented as a manual text entry field with limited integration between diagnosis selection and subsequent order creation. The replacement design separates these into two distinct, structurally linked subsections.

The Assessment section provides real-time ICD-10 diagnosis search through a type-ahead query interface. As the physician types a diagnosis term, the system returns matching codes ranked by frequency of use at the practice level. A side panel of modifiers allows code specificity to be refined from a general code to a more specific one without restarting the search. For example, a search for "diabetes type 1" returns E10 (Type 1 diabetes mellitus) as the base code, with the modifier panel offering E10.31 (Type 1 diabetes mellitus with unspecified diabetic retinopathy) as a refinement option if retinal findings are documented elsewhere in the note. This design reflects the N2C2 2022 Track 3 finding that Assessment and Plan sections are the most clinically critical components of progress notes and the primary site of diagnostic decision-

making [9].

Figure 2 below presents the complete workflow architecture of the encounter note, from patient check-in through Superbill review to billing claim submission. The diagram illustrates the sequence of documentation sections, the structural linkage layer between ICD-10 and CPT codes, and the API optimization component that reduces redundant server calls.

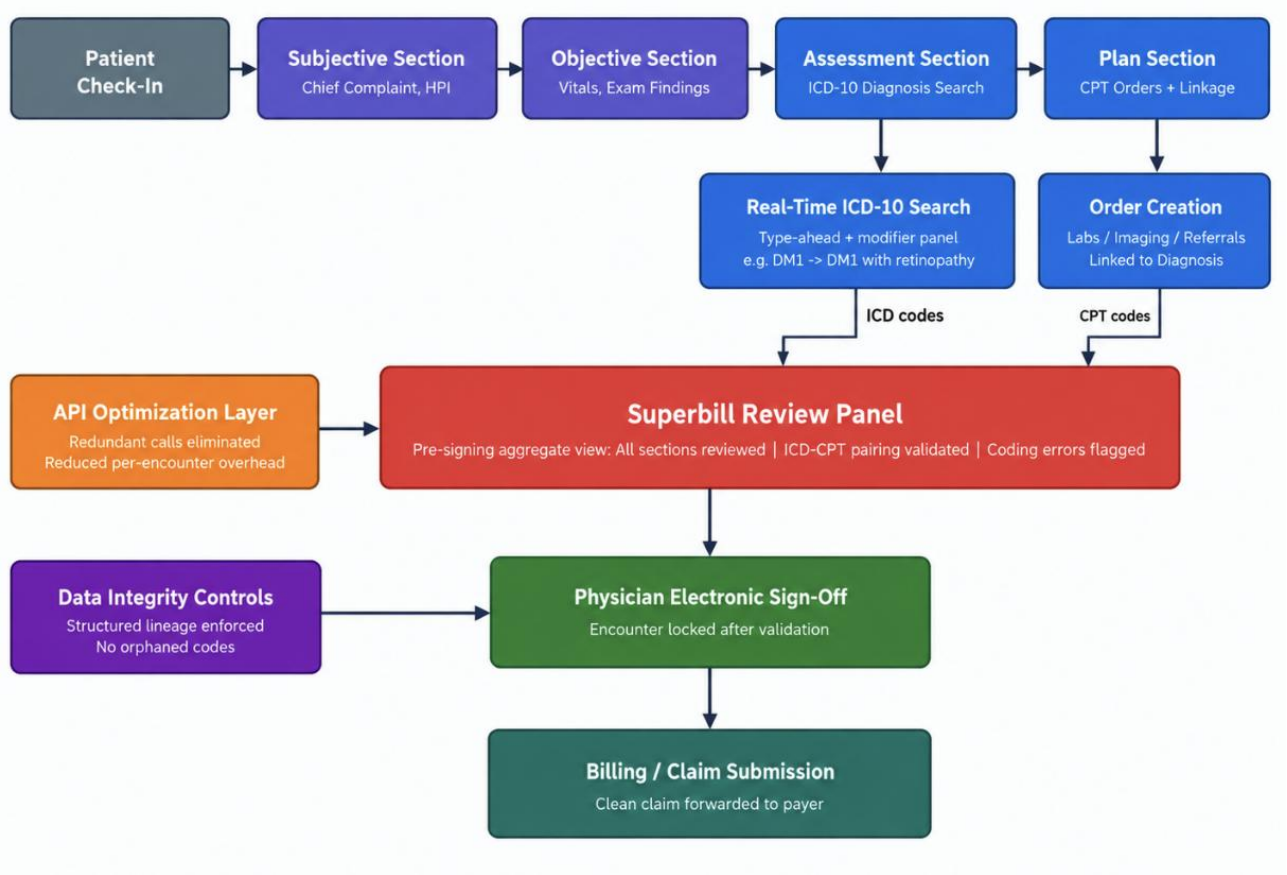


Figure 2. Encounter Note Workflow: Assessment, Plan, Superbill Review, and Billing Submission (compiled by the author based on [1, 3, 5, 9, 17]).

The Plan section captures visit parameters, including whether the encounter is telehealth or in-person and the start and end time of the visit, both fields required by CMS for E/M code level determination. Orders (laboratory tests, imaging studies, referrals) are created within this section with a mandatory binding to a parent diagnosis from the Assessment section. An order submitted without a linked diagnosis is rejected by the interface with an inline validation message, requiring the physician to either link the order to an existing diagnosis or add a new diagnosis before proceeding. This structural enforcement removes the possibility of orphaned CPT codes that reference no clinical indication, one of the most common sources of claim denials documented in the literature [7, 10].

The design principle underlying this section was informed by EHR usability research that identifies forced workflow steps as effective, when implemented without excessive friction, at reducing coding errors. Strawley et al. (2023) demonstrated that hospital web application performance is directly linked to interface structure, and that reducing the number of procedural steps required for high-frequency tasks substantially reduces both completion time and error rate [11]. The Plan section in the author-designed system reduces the steps required to create a linked order from approximately six clicks in the legacy system to three, while adding the structural validation step as a single modal confirmation rather than a separate form.

Before the physician electronically signs the encounter, the system presents a Superbill review panel that aggregates all sections of the visit into a single scrollable screen. This panel displays: all diagnoses selected

in Assessment with their full ICD-10 codes; all orders created in Plan with their CPT codes and linked diagnoses; visit parameters including mode, timing, and provider credentials; and any system-generated alerts for missing data or code specificity recommendations.

The Superbill panel serves as a pre-billing error detection checkpoint. Its design is motivated by the finding documentation that claims are frequently denied when CPT codes do not support medical necessity for the listed ICD codes, or when modifier use is inconsistent [8, 12]. Rather than relying on post-submission claim scrubbing, which adds latency to the revenue cycle and requires separate software or staff effort, the author-designed system positions error detection at the point of documentation, where the physician has full clinical context to make corrections.

Figure 3 presents the decision framework comparing commercial EHR adoption against custom platform development, with both case project outcomes shown as downstream branches. This framework synthesizes the literature on build-versus-buy decisions in healthcare IT with the observed data from Projects 1 and 2.

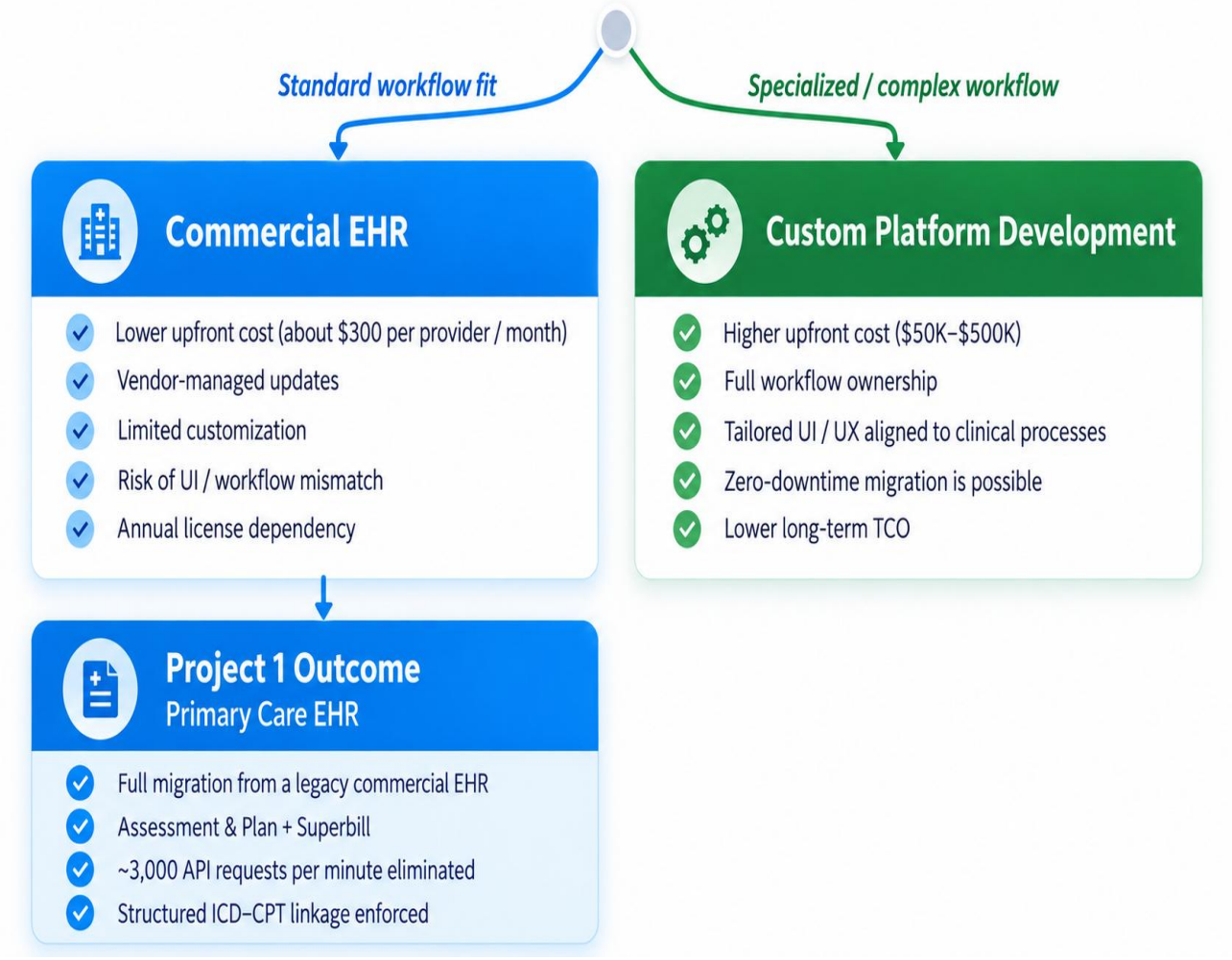


Figure 3. Design Framework for Transition from a Commercial EHR to a Custom Primary Care Platform at Oak Street Health (compiled by the author based on [1, 16, 20, 23]).

The author proposes that a Superbill panel designed as a mandatory pre-signing step, rather than an optional review, creates a structural behavior change in the encounter documentation process. Physicians who are required to review aggregated codes before signing are more likely to identify mismatches at the point of care than when reviewing a submitted claim denial days later. This is consistent with human factors research on error detection, which consistently shows that immediate feedback loops are more effective at behavior correction than delayed consequence feedback [5].

The API optimization work performed during development of this encounter note module produced an

estimated reduction of approximately 3,000 server requests per minute at projected peak load. This figure is calculated as the product of expected concurrent users per minute and the number of redundant API calls identified and eliminated during code review. Nevertheless, the pattern of redundant API call elimination in healthcare web applications is documented as one of the primary optimization strategies for clinical system performance [11].

Table 1 presents a systematic comparison of commercial EHR platforms against the custom-built system across key criteria relevant to primary care workflow, billing accuracy, and total cost of ownership. The comparison draws on published literature and author project data.

Table 1. Comparison of Commercial EHR Platform vs. Custom-Built System Across Key Operational Criteria (compiled by the author based on [1, 3, 4, 6]).

Criterion	Commercial EHR (Greenway and comparable platforms)	Custom-Built Platform
Implementation investment	Primarily recurring licensing, configuration, integration, and vendor-service costs	Substantial internal engineering investment across multiple frontend, backend, and supporting teams; total implementation cost was not calculated in this case study
Long-term cost structure	Ongoing licensing, integration, support, and vendor-dependent costs	Greater internal ownership of development and maintenance costs; long-term TCO and breakeven point were not measured at the assessment stage
Workflow customization	Constrained by vendor-supported templates, configuration options, and release cycles	Greater control over workflow design; encounter-note components can be developed around organization-specific clinical processes
ICD/CPT data integrity	Coding relationships depend on the functionality and validation mechanisms provided by the vendor system	Diagnosis-to-order linkage is enforced at the application layer in the encounter-note design
Migration and deployment risk	Transition may require configuration, data migration, user retraining, and temporary operation across systems	Requires staged migration, clinical workflow validation, and data-mapping verification; production downtime was not measured in this case
Scalability and system evolution	Capacity and feature evolution depend partly on vendor architecture, contracts, and product roadmap	Architecture and feature evolution are controlled internally, subject to organizational engineering capacity and infrastructure constraints
Support model	Vendor support governed by contractual service arrangements and internal escalation processes	Greater reliance on internal engineering and support teams; post-migration support-volume change was not measured
Platform governance	Core platform roadmap, pricing, and system capabilities remain substantially vendor-controlled	Organization retains greater control over application architecture, workflow changes, and development priorities

Note. EHR = Electronic Health Record; TCO = Total Cost of Ownership; ICD = International Classification of Diseases; CPT = Current Procedural Terminology.

The cost advantage of commercial EHR platforms diminishes substantially over time when implementation, customization, integration, and ongoing license costs are fully accounted for. A 2024 industry analysis found that providers spend on average $31,710 more per year on their EHR than their initial vendor quote suggested, and that 42% of practices cited integration costs as their primary financial pain point. The custom-built system, while requiring a higher upfront engineering investment, enables full ownership of the codebase, elimination of per-seat licensing, and workflow evolution without vendor approval cycles.

Table 2 provides a direct comparison of feature-level differences between the legacy Greenway system and the author-designed custom encounter note across the six primary documentation sections of the visit card.

Table 2. Feature-Level Comparison: Legacy Commercial EHR vs. Custom Encounter Note Design (compiled by the author based on case data and [5, 8, 9, 19, 22, 24]).

Section	Legacy System (Greenway)	Custom Platform	Improvement Introduced
Diagnosis entry (Assessment)	Manual text entry; no real-time ICD lookup	Type-ahead ICD-10 search with modifier panel	Reduces miscoding risk and supports greater code specificity
Orders (Plan)	Unlinked order list; no diagnosis binding	CPT orders structurally bound to parent ICD code	Prevents orphaned codes and strengthens billing-data integrity
Visit parameters	Manual time/mode entry; inconsistent	Mandatory telehealth/in-person flag; start/end time fields	Improves completeness and consistency of visit documentation
Pre-signing review	No integrated superbill; post-signing corrections only	Superbill panel aggregates all sections before sign-off	Enables pre-billing error detection and review of codes in clinical context

Note. DM1 = Type 1 Diabetes Mellitus; CPT = Current Procedural Terminology.

Figure 4 presents the data integrity architecture underlying the Superbill validation layer, illustrating how physician input flows through the structural linkage engine before reaching the pre-signing validation step and resulting in one of three outcomes: clean claim submission, audit trail log, or coding error flag requiring physician action.

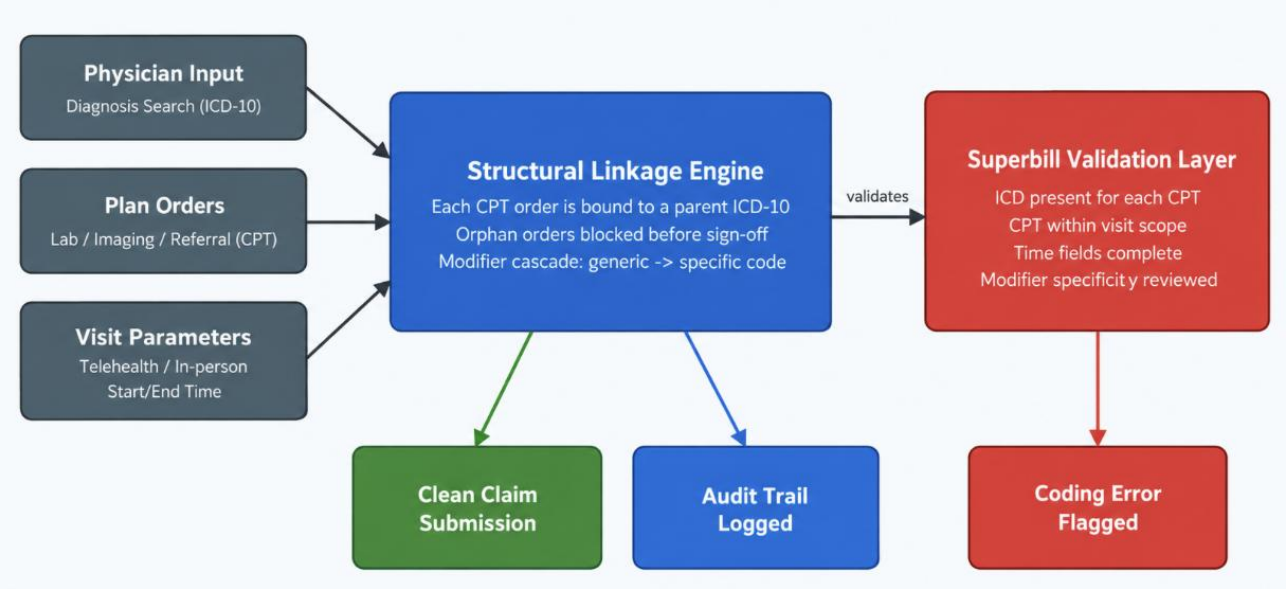


Figure 4. Data Integrity Architecture: ICD-CPT Structural Linkage and Superbill Validation Flow (compiled by the author based on [3, 8, 9, 20, 21]).

Within the Oak Street Health project, the transition to a custom EHR was guided by the principle that the replacement system should address documented workflow failures of the legacy platform rather than reproduce the Greenway interface field for field. This principle is most visible in the redesign of the Assessment and Plan workflow around diagnosis-first ordering, mandatory diagnosis-to-order linkage, and pre-signing Superbill review. Because full production deployment had not been completed at the assessment stage, migration continuity and post-launch operational outcomes should be treated as implementation objectives requiring subsequent validation rather than as demonstrated results.

Based on the literature synthesis and the Oak Street Health case analysis, this section presents design recommendations for engineering teams undertaking similar encounter-note or EHR modernization projects. These recommendations extend beyond the case-specific findings to address generalizable patterns identified across the research.

First, the author recommends that structural ICD-to-CPT linkage be implemented as an application-layer constraint rather than a post-submission validation rule. When the constraint exists only in the claim scrubber, physicians receive no immediate feedback during documentation and must re-engage with the encounter after sign-off to make corrections. Application-layer enforcement at the order creation step eliminates the cognitive lag between the clinical decision and its coding representation. This is consistent with the human factors literature on immediate feedback loops and error prevention in complex interfaces [5].

Second, the author recommends that pre-signing review panels be designed as mandatory workflow steps rather than optional summaries. The Superbill panel in Project 1 is triggered automatically as the final step of encounter documentation, appearing before the sign button becomes active. This design prevents the panel from being skipped under time pressure, which is the condition most likely to produce coding errors in primary care, where physicians routinely see 20 or more patients per day [4].

Third, the author recommends that migration from a commercial EHR to a custom platform be staged around clinical workflow validation rather than framed solely as a one-time technical cutover. In the Oak Street Health context, this means validating encounter documentation, diagnosis-to-order linkage, Superbill review, and clinical-data mapping before production transition. The EHR transition literature documents substantial operational and user burden during system changes, supporting staged validation and explicit workflow-readiness assessment [23-25].

Fourth, the author recommends that API optimization be treated as a first-class design concern in EHR

development rather than as a post-deployment remediation task. In the Oak Street Health project, a systematic audit of API call patterns during feature development eliminated redundant calls corresponding to a projected reduction of approximately 3,000 requests per minute at peak load. Because this estimate was produced before full production deployment, it should be interpreted as a design-stage performance projection requiring runtime validation [11, 15].

Conclusion

This article has examined three interconnected dimensions of primary care EHR transition: clinical workflow integration in the encounter note, interface usability in the Assessment and Plan section, and structural data integrity through ICD-to-CPT order linkage and pre-signing Superbill review. The analysis combined a systematic literature review with one original engineering case from the Oak Street Health EHR modernization effort.

The central hypothesis of the study, that structural application-layer enforcement of diagnosis-to-order binding reduces coding error exposure more reliably than post-submission claim scrubbing, is supported by both the literature and the design evidence from Project 1. The proposed architecture positions error detection at the point of documentation, within the Superbill review panel, before the encounter is signed and before a claim is submitted to the payer. This design change addresses the root cause of a billing problem that the literature attributes to interface-level failures rather than physician knowledge gaps [5, 7, 8].

Because the Oak Street Health project had not yet reached full production at the time of assessment, this study does not claim observed reductions in support volume, maintenance cost, transaction fees, or migration downtime. Its contribution is instead the documented design of application-layer coding controls, the integration of mandatory pre-signing review, and the explicit distinction between implemented design changes and projected performance effects. Production deployment will be required to quantify claim-denial changes, support burden, and infrastructure impact.

The practical significance of this work lies in its engineering-level specificity. The recommendations are directly actionable by software engineers and technical leads working on EHR modernization projects, without requiring changes to clinical protocols or billing regulations. The structural ICD-to-CPT linkage architecture, the mandatory Superbill review step, staged workflow validation, and early API optimization are design choices that can be adopted independently or in combination, depending on the constraints of each organization.

Future research should examine the runtime performance outcomes of the structural ICD-to-CPT linkage design once the primary care EHR is in full production, including claim denial rate before and after implementation, physician time-on-task for encounter documentation, and API response time under real clinical load. The comparison of pre-signing error detection rates against post-submission denial rates would provide empirical validation of the hypothesis tested in this article, and would contribute to the growing body of evidence linking EHR interface design choices to healthcare revenue cycle outcomes.

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