

The Benefits of Integrating EMR Systems between Primary and Specialist Care Institutions: A Mixed-Method Study

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The Benefits of Integrating EMR Systems between Primary and Specialist Care Institutions: A Mixed-Method Study

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Abstract

Background: The benefits of a fully integrated EMR system across primary and specialist care institutions have yet to be formally established. Integrating the EMR systems between primary and specialist care is the first step in building a medical neighborhood. A medical neighborhood is a set of policies and procedures implemented through integrated systems and processes that support the joint management of patient care across primary care physicians (PCPs), specialist physicians, and other healthcare providers.

Objective: This study aims to quantify the impacts of integrating the EMR systems of primary and specialist care institutions in the process of developing a medical neighborhood. The impacts are operationalized in both quantitative and qualitative measures, measuring the benefits of such an integration in three specific areas, namely patient diagnosis tracking, patient care management, and patient coordination.

Methods: A comprehensive, mixed-method examination using three different data sources (EMR consultation data, clinician survey data, and in-depth interviews) was conducted. The EMR data consists of patient encounters referred to a specialist clinic from six primary care providers before and after integrating the EMR system into the primary and specialist care institutions. We analyzed 25,505 specialist consultation episodes referred to the specialist clinics by the primary care partners for a 12-month period, during which the integration of the EMR system was conducted. Econometric modeling was used to identify the quantitative impacts of the EMR integration, and a follow-up survey was conducted on the clinicians 18 months post-integration. The clinicians' perception of the integration was measured to triangulate the empirical observation from the patient encounters and the post-implementation perception survey was analyzed to triangulate the earlier econometric results. Concurrently, a total of 30 interviews were conducted between 16 Mar 2021 to 28 Jul 2021 with clinicians and operations staff to gather on-the-ground sentiments engendered by this integration which further inform our quantitative findings.

Results: The integration of EMR systems between primary and specialist care institutions was associated with benefits in patient diagnosis tracking, patient care management, and patient coordination. Specifically, it was found that the integration resulted in a decrease in wait time for specialist appointments of an average of 16.5 days ($p < 0.01$). Patients were also subjected to less repeated procedures and tests; the number of procedures, X-rays, and overall bill sizes all decreased to between 7.8% and 39.7% ($p < 0.01$), resulting in reduced healthcare resource wastage while maintaining similar medical outcomes ($p > 0.1$).

Conclusions: Our study's results are among the first instances of empirical evidence to show that the integration and sharing of

data between primary and specialist care institutions promote continuity in healthcare delivery and joint patient management in a medical neighbourhood. The findings go beyond the traditional benefits of improved referral communication, as shown in prior literature.

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Original Manuscript

Original Paper

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The Benefits of Integrating EMR Systems between Primary and Specialist Care Institutions: A Mixed-Method Study

Abstract

Background

The benefits of a fully integrated EMR system across primary and specialist care institutions have yet to be formally established. Integrating the EMR systems between primary and specialist care is the first step in building a medical neighborhood. A medical neighborhood is a set of policies and procedures implemented through integrated systems and processes that support the joint management of patient care across primary care physicians (PCPs), specialist physicians, and other healthcare providers.

Objective

This study aims to quantify the impacts of integrating the EMR systems of primary and specialist care

institutions in the process of developing a medical neighborhood. The impacts are operationalized in both quantitative and qualitative measures, measuring the benefits of such an integration in three specific areas, namely patient diagnosis tracking, patient care management, and patient coordination.

Methods

A comprehensive, mixed-method examination was conducted using three different data sources (EMR consultation data, clinician survey data, and in-depth interviews). The EMR data consists of patient encounters referred to a specialist clinic from six primary care providers before and after integrating the EMR system into the primary and specialist care institutions. We analyzed 25,404 specialist consultation referrals to the specialist clinics by the primary care partners for a 12-month period, during which the integration of the EMR system was conducted. A cohort empirical investigation was used to identify the quantitative impacts of the EMR integration, and a follow-up survey was conducted with the clinicians 18 months post-integration. The clinicians' perceptions of

the integration were measured to triangulate the empirical observation from the patient encounters, and the post-implementation perception survey was analyzed to triangulate the empirical investigation of consultation instances of the earlier cohort. Concurrently, a total of 30 interviews were conducted between 16 March 2021 to 28 July 2021 with clinicians and operations staff to gather on-the-ground sentiments engendered by this integration, which further informed our quantitative findings.

Results

The integration of EMR systems between primary and specialist care institutions was associated with benefits in patient diagnosis tracking, patient care management, and patient coordination. Specifically, it was found that the integration resulted in a decrease in wait time for specialist appointments of an average of 16.5 days ($p < 0.01$). Patients were also subjected to less repeated procedures and tests; the number of procedures, X-rays, and overall bill sizes all decreased by between 7.8% and 39.7% ($p < 0.01$), resulting in reduced healthcare resource wastage while maintaining similar medical outcomes ($p > 0.1$).

Conclusion

Our study's results are among the first instances of empirical evidence to show that the integration and sharing of data between primary and specialist care institutions promote continuity in healthcare delivery and joint patient management in a medical neighborhood. The findings go beyond the traditional benefits of improved referral communication, as shown in prior literature.

Keywords: EMR integration, primary care, specialist care, medical neighborhood, efficiency

Introduction

The problem of patient referral and coordination between primary and specialist care continues to be an ongoing challenge. In 2005, the average primary care physician (PCP) in the United States needed to coordinate patient care with 229 other physicians in as many as 117 practices [1], and such figures are representative of health systems where the aging population and number of healthcare providers are growing in tandem. However, such an inter-institution fragmentation of care, as shown in a literature review published in 2020 [2] is associated with poorer health outcomes. The Department of Health and Human Services (United States) defines care coordination as “the deliberate organizing [of] patient care activities and sharing [of] information among all of the participants concerned with a patient's care to achieve safer and more effective care” and identified health information technology as a critical resource in this endeavor. Despite the need for close coordination among different healthcare providers, IT-enabled communication between primary and specialist care institutions is limited, which has negatively impacted patient care continuity [3].

Prior studies and the American College of Physicians have proposed the patient-centered medical neighborhood (PCMH-N) framework to promote coordinated care between PCPs and other providers for a given group of patients [4-8]. A medical neighborhood essentially involves a set of policies and procedures implemented through integrated systems and processes that support the joint management of patient care across PCPs, specialist physicians, and other healthcare providers [9, 10]. If implemented correctly, PCMH-N will lead to faster and more appropriate referrals for specialist care with less wastage and repeated medical diagnostics, and as a result, patients can expect better care outcomes [3, 9, 11, 12].

In Fisher's [4] seminal work, five components were identified and weighted in terms of their importance in the implementation of PCMH-N; among them, the use of integrated health IT systems

for **patient diagnosis tracking** (i.e. to have synchronous EMR systems track patients' diagnoses, test results, prescriptions, etc. across different institutions) is ranked top and accounts for 50% of the total resources required. Systems and guidelines to ensure **patient care management** and **patient coordination** (referrals across institutions) are ranked second, which accounts for 15% of the resources required. Developing communications standards, developing patient care plans, and performance reporting are the other three components that jointly account for the remaining 35% of the resources required. In this study, focus was placed on measuring the aforementioned components that ranked most important in building a PCMH-N (i.e., patient diagnosis tracking, patient care management, and patient coordination), and these measures were used to guide the study's research design and data collection. The overall objective of this mixed-method study is to conduct an implementation assessment of the benefits of a fully integrated EMR system across different PCPs and specialist care healthcare institutions. We examined the benefits using three dimensions. First, in the area of **patient diagnoses tracking**, we measured whether the synchronous flow of complete patient clinical data among PCPs and specialists, as well as the communication among PCPs, specialists, and their administrative teams would result in a reduction of repeated lab tests, diagnostic radiology tests, and overall patient bill sizes. Second, in the area of **patient care management**, we examined whether there were differences in patient outcomes and reductions in medical procedures due to the EMR integration. Third, in the area of **patient coordination**, we measured if the EMR integration and standardized referral process improved tracking and follow-up among primary care clinics and specialist clinics thereby leading to shorter wait times for specialist appointments.

The purpose of this research is to measure the effects of integrating EMR systems between primary and specialist care institutions. To achieve this objective, three types of data were used: patient encounter data from the EMR system (Data Source 1, DS1), clinician survey data (Data Source 2, DS2), and interviews (Data Source 3, DS3). Our study aims to provide a comprehensive

understanding of the benefits of a fully integrated EMR system across different healthcare institutions to develop a PCMH-N. The findings of this research can serve as a guide for other healthcare organizations on how to successfully implement an integrated system.

Methods

Data Collection and Data Sources

Data Source 1 (DS1): EMR data collection

We collected data from a cohort of 25,404 patient encounters referred from six primary care clinics to various specialist clinics from 1 April 2020 to 31 March 2021. The inclusion criteria are all specialist care referrals from the six primary care clinics referred to the specialist clinic for the period. No sampling was performed to reduce sampling or selection biases. Each of these six primary care clinics typically handles about 800 consultations per clinic per day, of which there are instances where patients have to be referred to a specialist clinic. The data was extracted from the electronic medical records system of the health institutions. Of these referrals, 22,309 have complete data; the remaining 3,095 encounters have some missing data due to the patient not turning up for the appointment. The observations with some missing variables were list-wise omitted from the analysis if the missing variables are part of the model specification, there is no imputation of missing data, and the missing rate is equivalent to institutions' historical averages. Additional details of the collection methodology are reported using the STROBE guidelines and can be found in Appendix 1.

Between 26 September 2020 and 16 November 2020, the primary care clinics changed to a new EMR system that was integrated with those in the specialist clinics. The integration involves synchronous, read-and-write access to the medical notes, patient scheduling, and viewing of all patient medical records, including laboratory tests, x-rays, etc., by both the PCPs and specialist care

clinicians. As a result, the referral process for the primary care clinics was standardized in the EMR system. The EMR integration was performed on a weekend when the consultations for the weekend were suspended. 14,124 encounters in the specialist clinics occurred before the integration, and 11,280 encounters occurred after the integration.

Data Source 2 (DS2): Clinician Survey

As suggested in the literature [13], we surveyed clinicians in both primary and specialist care institutions to gain insights into the factors potentially driving any difference in the management of referrals. The survey was emailed to all clinicians working in primary and specialist care clinics in June 2022 who are impacted by the integration of the EMR system. A total of approximately 200 clinicians were emailed. Due to the confidentiality agreement with the healthcare institutions, these emails were sent to the clinicians via the hospital network and not by the researchers. A total of 103 clinicians replied to the survey (81 from the primary care clinics and 23 from the specialist clinics) at a 95% confidence level; the margin of error for the survey was 6.7%. The survey responses were anonymised, and all responses were retained for analysis and reporting.

Data Source 3 (DS3): In-depth interviews

In addition to the survey, the researchers also conducted in-depth qualitative interviews with different stakeholders. The data collection period was from 16 March 2021 to 28 July 2021. Interviewees were selected based on purposive sampling to have a diverse set of interviewees involved in the referral process. As such, we selected interviewees from: a) those who worked in the specific specialist clinics (chosen for the high volume of referrals received from the primary care clinics), b) the call center, and c) those in specific primary care clinics (chosen for sending high number of referrals to the specialist clinics). Within those clinics and call center, we selected those who were held clinical and non-clinical roles and were involved in the referral process (from writing the referral, to

processing, scheduling, and receiving the referrals). As our goal was to understand the perceptions of the clinicians and admin staff concerning the EMR integration and its impact on the referral process, invitations for interviews were sent via email more than three months after the integration. This would provide a more balanced perception of the integration after a significant period of use. A total of 30 interviews were conducted – 15 at the specialist clinic and call center (clinicians, clinic managers, call center staff), and 15 at the primary care clinics (PCPs, managers, referral admin staff). Refer to Table 1 for the breakdown of the interviews by the interviewees' respective roles and organizations.

Table 1. Number of Interviews by Roles and Organization

	Number of Interviews Post-EMR Integration
Specialist Clinics	
Specialists (and specialist nurses)	9
Clinic Manager	2
Call Center Admin Staff	4
Subtotal	15
Primary care clinics	
PCPs	6
Manager	3
Referral Admin Staff	6
Subtotal	15
Total	30

Note: Each count represents an interview instance with a unique staff member lasting between 30 to 60 minutes. Refer to Appendix 2 for more details about the selection methodology.

Interviews were conducted either at the interviewees' office or via online mode (Zoom). The duration of each interview was between 30 minutes to an hour and they were conducted by two interviewers. A set of standardized interview questions was used, but the interviewers allowed the interviewee to guide them based on what they felt was more salient based on their experience. Most of the interviews had audio recordings and were transcribed after each interview. For those that were not recorded, copious notes were written. Additional details of the interview methodology are detailed

using the COREQ checklist (COnsolidated criteria for REporting Qualitative research) in Appendix 2.

Analysis of Data Collected

DS1: Analyzing EMR Data

We collected details relating to all the referral patient encounters between the six primary care clinics and the specialist care clinic. The unit of analysis for the estimation is per patient referral encounter, j , where:

$$y_{ij} = f(X_{ij}, Z_{ij}, U_i)$$

where y represents six continuous dependent variables and one binary dependent variable (details below). X represents the vector of control variables, Z is a binary variable representing pre- and post-EMR integration, U_i represents the specific error term for each primary care clinic, and i .

The outcome variables, y . The six continuous dependent variables were measured to operationalize the benefits of patient diagnosis tracking, care management, and coordination. These dependent variables were: 1) the patient's wait time for a specialist appointment (patient coordination), 2) the number of procedures conducted at a specialist clinic (patient care management), 3) the number of panel tests conducted at a specialist clinic (patient diagnosis tracking), 4) the number of lab tests conducted at a specialist clinic (patient diagnosis tracking), 5) the number of X-rays conducted at a specialist clinic (patient diagnosis tracking), and 6) the bill size of the specialist consultation (patient diagnosis tracking). Due to confidentiality reasons, bill sizes were standardized by dividing individual bill encounter sizes over the overall mean bill size of the dataset. If improved patient diagnosis tracking occurred, all else held constant, a reduction in the number of X-rays, lab tests, and overall bill sizes in the specialist clinics was expected, given that these reports from the primary care clinics had been made available to the specialists via the EMR integration. In order to measure

whether healthcare outcomes (patient care management) had changed post-EMR integration, the dependent variable of the resolution (or lack thereof) of the clinical encounter was recorded as a binary outcome.

The control variables X , for this estimation included medical specialty, the ICD-10 problem code, the procedure performed, the case's urgency as assessed by the PCP, the patient's gender, race, marital status, and visit date. These variables partialled out the majority of the confounding factors that would impact the referral process.

We used both Fixed Effects Feasible Generalized Least Squares (FE-FGLS) and Random Effects Feasible Generalized Least Squares (RE-FGLS) estimators to analyze the relationship between the six outcome variables represented by Y , the independent variables represented by X and Z for all the referral encounters from 1 April 2020 to 31 March 2021. This methodology accounts for unobserved, time-invariant heterogeneity by including unit-specific intercepts and addresses potential heteroscedasticity or serial correlation in the error terms. Specifically, the estimation procedure involves two steps: (1) fixed effects (and random effects) are initially estimated using ordinary least squares (OLS); (2) residuals from the first step are used to construct a feasible generalized least squares (FGLS) weighting matrix for a second-step estimation. Robust standard errors are reported to account for possible heteroskedasticity of the data.

For fixed effects and random effects estimations, we used the grouping variable of each primary care clinic to account for time-invariant primary care clinic characteristics and the source of the primary care clinic referral. The estimation was conducted in Stata 18 using the XTREG function for all six fixed-effects and six random-effects feasible generalized least squares (FGLS) [14]. These would help us estimate the post-effects of the EMR integration for the medical neighborhood.

Finally, we also performed one fixed-effects and one random-effects logistic regression [15] to estimate the above specification with the binary dependent variable of whether the clinical encounters were resolved. The estimation was conducted in Stata 18 using the XTLOGIT function. Likewise, the results were reported according to the STROBE Guidelines, as documented in Appendix 1.

DS2: Analyzing Survey Data

To triangulate our empirical results from the consultation records [16], we conducted a secondary analysis to measure the perceptions of both primary and specialist care clinicians in five areas, specifically, 1) their access to clinical notes, 2) their access to test results, 3) referral appointment scheduling, 4) referral management, and 5) quality of care. Items 1 and 2 measured patient diagnosis tracking, items 3 and 4 measured patient coordination, and item 5 measured patient care management.

For each category, we surveyed clinicians 18 months post-implementation to gauge their sentiments about the possible changes brought about by the EMR integration. PCPs and specialists were asked to rate (on a 5-point scale) [17] if the EMR integration for the PCMH-N presented changes to their daily work in each area. The questions were edited to fit their primary care or specialist care contexts (refer to results Table 4 for details).

DS3: Analyzing Interview Data

We used qualitative content analysis to analyze the interview data collected after the implementation of the EMR system [18]. In order to have a better comparison between the two key stakeholders, the analysis was divided into primary care clinic and specialist clinic data. We compared the themes

emerging from the primary care clinics with those from the specialist clinics' data to observe their similarities and differences. The coding of interview data was conducted by one researcher and validated by a research associate. All of the interview data were coded using MaxQDA (version 2020). Overall, our coding analysis generated themes that we mapped to our survey, i.e., access to referral notes and tests, referral scheduling and management, and overall quality of care. Further, we surfaced important differences between the PCPs' and specialists' perceptions within some of the themes. Interview texts were included in the results to illustrate these themes.

Ethical Considerations

The ethics approval for this study was obtained on 8 September 2020 from the National Healthcare Group (NHG), Domain Specific Review Board (DSRB), Singapore (NHG DSRB Reference number 2020/00156). This approval covered all three data sources. Informed consent for data sources DS2 and DS3 were explicitly obtained. For DS1, under the Human Biomedical Research Act 2015, informed consent is deemed to be obtained for deidentified, archival medical records. All data collected were deidentified, and human subjects were not compensated for participating in this research.

Results

Both sets of random and fixed effects estimation yielded similar results. For brevity, unless specified otherwise, we described the findings using the fixed effects estimation (Table 3a).

In terms of *patient diagnosis tracking*, we observed some improvements in patient tracking through the EMR integration. First, we observed a significant reduction in the number of X-rays conducted after the integration (coefficient -0.0408, $P < 0.05$). This translates to a 39.6% decrease in the number of X-rays post-integration when the coefficient is divided by the mean number of X-rays

conducted for all procedures. The synchronous availability of X-ray scans and reports between primary and specialist care institutions perhaps reduced the need for specialist clinics to perform repeated X-rays.

Intuitively, with the reduction in the number of procedures and X-rays, the regressions showed an overall decrease of 7.80% in bill size after the EMR integration ($P < 0.01$). The integration, however, did not bring about a reduction in resource use in other areas. Specifically, there were no changes observed in the number of lab tests conducted at the specialist clinics after the integration ($P = 0.641$). Similarly, the estimation results provided minimal statistical support for a reduction in the number of panel tests conducted after the EMR integration (Fixed Effects coefficient = -0.0159, $P = 0.142$; Random Effects coefficient = -0.0164, $P = 0.057$). We discuss some of the possible reasons for these results in the Discussion section below.

In terms of ***patient care management***, a significant drop was observed in the number of procedures conducted at the specialist clinic by coefficient -0.0398, $P < 0.01$, which translates to a 30.4% drop in procedures. This is calculated by dividing the drop by the mean number of procedures for all consultations by 0.131. Similarly, no changes were observed in the number of encounters marked as resolved after the consultation ($P = 0.373$), suggesting no significant aggregated change in medical outcomes after integrating the primary and specialist care EMR systems.

Finally, our results showed improvements in ***patient coordination***. Based on the descriptive statistics (Table 2a), we observed that the mean wait time was shortened from 34.65 days to 21.03 days over 12 months, during which the EMR had been integrated between the primary and specialist care clinics. The FLGS estimation (Table 3a) also showed that the average wait time for a referral from primary to specialist care decreased by 16.49 days ($P < 0.001$) after the EMR integration.



Table 2a. Descriptive Statistics of Dependent Variables from EMR System (Before and After Integration)

Variable	Construct	Before integration				After integration			
		Mean	Std. Dev.	Median	IQR	Mean	Std. Dev.	Median	IQR
Wait time (days) to referral appointment date	Patient Coordination	34.651	32.352	26	[8,52]	21.040	19.970	13	[5, 35]
No. of procedures at specialist clinic	Patient care management	0.122	0.384	0	[0,0]	0.146	0.411	0	[0,0]
No. of panel tests at specialist clinic	Patient diagnosis tracking	0.101	0.520	0	[0,0]	0.100	0.540	0	[0,0]
No. of lab tests at specialist clinic	Patient diagnosis tracking	0.068	0.411	0	[0,0]	0.068	0.417	0	[0,0]
No. of X-rays at specialist clinic	Patient diagnosis tracking	0.100	0.416	0	[0,0]	0.108	0.423	0	[0,0]
Bill size (index dollars)	Diagnosis tracking	0.998	0.750	0.717	[0.611, 1.130]	1.011	0.710	0.717	[0.611, 1.164]
Condition resolved	Patient care management	0.044	0.205	0	[0,0]	0.045	0.207	0	[0,0]

Note: IQR represents interquartile range. Std Dev. represents standard deviation.

Table 2b. Descriptive Statistics of Dependent Variables from the EMR System

Variable	Construct	Overall			
		Mean	Std. Dev.	Median	IQR
Wait time (days) to referral appointment date	Patient Coordination	29.775	29.277	20	[7,46]
No. of procedures at specialist clinic	Patient care management	0.131	0.394	0	[0,0]
No. of panel tests at specialist clinic	Patient diagnosis tracking	0.101	0.527	0	[0,0]
No. of lab tests at specialist clinic	Patient diagnosis tracking	0.068	0.413	0	[0,0]
No. of X-rays at specialist clinic	Patient diagnosis tracking	0.103	0.419	0	[0,0]
Bill size (index dollars)	Diagnosis tracking	1.000	0.743	0.717	[0.611, 1.137]
Condition resolved	Patient care management	0.045	0.206	0	[0,0]

Note: IQR represents interquartile range. Std Dev. represents standard deviation.

Table 3a. Results from Fixed Effects Estimation for Specialist Clinic Referrals

Dependent Variable	Construct	Fixed Effects, FGLS Estimation				
		Coeff.	Std. Dev.	P-value	95% CI	R ²
Wait time (days) to referral appointment date	Patient coordination	-16.4933	0.7257	<0.001	[-18.3587, -14.6280]	0.335
No. of procedures at specialist clinic	Patient care management	-0.0398	0.0086	<0.01	[-0.0618, -0.0178]	0.292
No. of panel tests at specialist clinic	Patient diagnosis tracking	-0.0159	0.0092	0.142	[-0.0395, 0.0076]	0.403
No. of lab tests at specialist clinic	Patient diagnosis tracking	-0.0064	0.0130	0.641	[-0.0398, 0.0270]	0.445
No. of X-rays at specialist clinic	Patient diagnosis tracking	-0.0408	0.0125	<0.05	[-0.0730, -0.0085]	0.274
Bill size (index dollars)	Patient diagnosis tracking	-0.0780	0.0156	<0.01	[-0.1181, -0.0379]	0.532
Condition resolved	Patient care management	-0.0973	0.1092	0.373	[-0.3113, 0.1168]	N.A.

Note: We anonymized the actual bill size for confidentiality reasons; the consultation bill sizes were divided by an index value – coefficients represent the drop in percentage of the bill size. Fixed and Random Effects OLS estimations were also performed with similar statistical results but not reported due to data heteroskedasticity.

Table 3b. Results from Random Effects Estimation for Specialist Clinic Referrals

Dependent Variable	Construct	Random Effects, FGLS Estimation				
		Coeff.	Std. Dev.	P-value	95% CI	R ²
Wait time (days) to referral appointment date	Patient coordination	-16.2349	0.6235	<0.001	[-17.4568, -15.0129]	0.335
No. of procedures at specialist clinic	Patient care management	-0.0392	0.0083	<0.001	[-0.0555, -0.0229]	0.292
No. of panel tests at specialist clinic	Patient diagnosis tracking	-0.0164	0.0086	0.057	[-0.0333, 0.0005]	0.403
No. of lab tests at specialist clinic	Patient diagnosis tracking	-0.0065	0.0130	0.617	[-0.0319, 0.0189]	0.445
No. of X-rays at specialist clinic	Patient diagnosis tracking	-0.0409	0.0126	<0.001	[-0.0656, -0.0162]	0.275
Bill size (index dollars)	Patient diagnosis tracking	-0.0787	0.0148	<0.001	[-0.1078, -0.0496]	0.532
Condition resolved	Patient care management	-0.0507	0.1173	0.666	[-0.2806, 0.1792]	N.A.

Note: We anonymized the actual bill size for confidentiality reasons; the consultation bill sizes were divided by an index value – coefficients represent the drop in percentage of the bill size. Fixed and Random Effects OLS estimations were also performed with similar statistical results but not reported due to data heteroskedasticity.

Survey and Interview Results

We analyzed the survey responses and interview data to triangulate the findings from the consultation records with the clinicians' sentiments on the ground. Table 4 below provides the survey results, where sentiment scores larger than 3 represent the positive change resulting from the integration, and values less than 3 present negative changes from the integration.

Patient Diagnosis Tracking

PCPs and specialists agreed that the EMR integration brought about greater accessibility to clinical notes, where they could read the details of the notes written by clinicians across primary and specialist care institutions (Primary care = 3.90, $P < 0.01$; Specialist care = 3.79, $P < 0.01$). This sentiment was reflected in a quote from a PCP who said, "I think it's easier to give a referral. They can look at our notes, and we can look at their notes – regarding what happened, what their discussion was. So, I think that's actually a convenience." A specialist concurred, saying, "Since we can access the notes, it is better than the previous time, as we can see what they have assessed. They would have enquired about their past medical history and drug allergies, and the reason for referral is also much clearer than before."

Likewise, PCPs found marginal improvement in the accessibility of standardized records such as lab tests (Mean = 3.33, $P < 0.1$), while the specialists perceived significant improvements in the accessibility of these standardized records (Mean = 4.23, $P < 0.01$). This improvement in notes also aided the specialist during patient examination: "Yes, it makes it more convenient (and) uniform, and I know that patient has a heart problem, a kidney problem, I can just further enquire, 'what medications are you taking?' rather than going all over again 'do you have any heart problem?'" (Orthopedic Specialist).

Patient Coordination

In terms of referral scheduling and referral management, we observed that PCPs did not perceive any positive changes in referral scheduling (Mean = 2.94, $P > 0.10$), but observed improved ease in referral management (Mean = 3.68, $P < 0.01$). The admin staff explained how the referral management improved for patients: “So now we are on the same platform – I see all of the patient’s appointments, whether it’s in the [primary care clinic] or the [specialist clinic]. It is good because when we schedule an appointment, we try to avoid the date the patient has to go to the [primary care clinic], or it helps us understand where the patients are going on different days.” The specialists also observed that referral scheduling became faster (Mean = 3.92, $P < 0.01$) and better managed (Mean = 3.5, $P < 0.05$). As shared by a specialist clinic staff who said, “Efficiency increased and productivity (of referrals) increased, because (we) don’t need to toggle between multiple applications to handle one referral.”

Patient care management.

Finally, both PCPs and specialists felt that the quality of care for the patients after the integration had improved (Primary care = 3.37, $P < 0.05$; Specialist care = 4.11, $P < 0.01$). A PCP shared how the EMR integration helped with improving quality of care: “I think the most relevant is the Cardio side, because they are running a clinic called the Rapid Access Chest Pain Clinic. So, usually, what we do is refer the patient to [the specialist clinic] for a very quick cardiac assessment. So, if they did the treadmill, the blood test comes back all normal, they will send [them] back to us to see. In this scenario, because we can see the Cardiology notes and their screening, ..., we can more easily follow up for these patients.”

Table 4. Results from Survey Post-EMR Integration for Medical Neighborhood

Category	Construct	Questions for Primary Care Clinicians	Mean SD p -value 95% CI
Access to clinical notes	Patient diagnosis tracking	I find that it is easier to access patient notes that [the specialist] clinicians have written [after the integration]	3.90 0.12 <0.01 [3.65, 4.15]

Access to test results	Patient diagnosis tracking	I find that it is easier to access lab tests and/or medication [after the integration]	3.33 0.20 <0.10 [2.94, 3.73]
Referral scheduling	Patient coordination	I observed that my clinic's patient could get his/her scheduled appointment at [the specialist clinic] at an earlier date	2.94 0.14 >0.10 [2.66, 3.22]
Referral management	Patient coordination	My work of managing patient referrals from specialists benefits from my access to [specialist] clinicians' patient notes and lab tests.	3.68 0.18 <0.01 [3.31, 4.04]
Category	Construct	Questions for Specialist Care Clinicians	Mean SD <i>p</i> -value 95% CI
Quality of care	Patient care management	I believe that [the integration] has enabled my clinic to provide better clinical care for my patients referred to [specialist care]	3.37 0.15 <0.05 [3.06, 3.68]
Access to clinical notes	Patient diagnosis tracking	Since [the integration], I feel that it is easier to access referral notes and/or patient notes written by the [primary care] clinicians and/or referral staff.	3.79 0.26 <0.01 [3.23, 4.35]
Access to test results	Patient diagnosis tracking	Since [the integration], I feel that it is easier to access a [primary care] referral patient's lab tests and medication lists	4.23 0.17 <0.01 [3.89, 4.59]
Referral scheduling	Patient coordination	Since [the integration], I observed that [primary care] referral patients had their appointment booked at an earlier date.	3.92 0.23 <0.01 [3.41, 4.42]
Referral management	Patient coordination	Since [the integration], I feel that accessing [primary care] referrals has become less time-consuming	3.50 0.23 <0.05 [3.01, 3.99]
Quality of care	Patient care management	[The integration] has helped me to improve overall clinical care and/or service to [primary care] referral patient	4.11 0.20 <0.01 [3.65, 4.57]

Note: Measures from a scale of 1 to 5, where 3 represents the mid-point where no change was perceived after the integration. Values larger than 3 represent a positive perception towards the integration, and values less than 3 represent a negative perception towards the integration. 2-sided *p*-values and 95% confidence intervals are reported. SD represents standard deviation.

Discussion

Principal Results

In this study, we triangulated the effects associated with EMR system integration using patient encounter records, survey, and interview data. The survey and interview results provided some explanations for our observations based on the quantitative outcomes associated with integrating primary and specialist care institutions. Figure 1 below presents an integrated summary of this study's findings by juxtaposing the three dimensions of impact

(i.e., patient diagnosis tracking, patient care management, patient coordination) resulting from the EMR integration, with the data sources and analysis from this study.



Figure 1: Summary of Findings

Data Source	Methodology	Impact Measured		
		Patient Diagnosis Tracking	Patient Care Management	Patient Coordination
DS1: Objective, patient encounter records	Cohort empirical investigation	<i>Improvements in 2 of 4 measures</i>	<i>Improvements in 1 of 2 measures</i>	<i>Improvement in 1 of 1 measure</i>
DS2: Perception, survey	Survey of clinicians	<i>Improvement observed in 3 of 4 measures</i>	<i>Improvement perceived in 2 of 2 measures</i>	<i>Improved perceived in 3 of 4 measures</i>
DS3: Perception, clinicians	In-depth interviews with clinicians	<i>Improvement perceived by PCP and specialists</i>	<i>Improvement perceived by PCP and specialists</i>	<i>Improvement perceived by staff doing patient scheduling</i>

Note: The table summarizes the quantitative findings based on the different measures used to operationalize the three constructs of patient diagnosis tracking, patient care management, and patient coordination. The qualitative findings from the in-depth interviews are juxtaposed with the quantitative findings.

Regarding patient diagnosis tracking, from the survey and interviews, both PCPs and specialists found that it became easier to access the clinical notes written by clinicians from other institutions after the EMR system integration. This sentiment was quantitatively supported by our cohort empirical investigation, as seen in the reduced number of examinations and treatment procedures conducted by the specialists during their consultations.

Interestingly, in terms of clinicians' perception regarding the improved accessibility of standardized test results (e.g., X-rays, lab tests), it was strongly felt by the specialists but less so by the PCPs. One possible reason for this is specialists may tend to read the PCPs' initial diagnosis during the consultation when patients are referred to them. In our empirical estimation, we observed that the number of X-rays decreased after the EMR integration, while laboratory panel tests saw a marginal decline, and standalone laboratory tests did not experience any decline after the EMR integration. Our interview data suggested that

specialists required laboratory tests to get more current readings from their patients, hence increasing the likelihood of conducting a repeated test during the specialist consultation, while specialists typically did not require additional X-rays if there were no material changes in the patient's condition.

The reduced number of X-rays and procedures conducted in specialist clinics without any additional increase in other forms of diagnosis was naturally associated with an overall drop in the patient consultation's bill size. As clinicians do not perform the patient's billing and it is an objective quantifiable measure, hence, we did not survey the clinicians concerning this aspect post-EMR implementation. An overall lower bill for the patient represents a more efficient use of medical resources in healthcare systems.

From the patient encounter records that measured patient care management quantitatively, we observed a drop in the number of procedures performed, with no associated drop in the resolution rate of diseases. Although we did not see an improvement in the resolution rate from the objective data, the clinician survey results suggested an improvement in the perceived quality of care provided. We believe the mixed results are due to the many definitions and measurements of the quality of care. Hence, we argue that perhaps care improvements cannot be fully measured with just the resolution rate of clinical problems measure. Instead, by adopting the clinicians' broader perspective, we could observe some improvements in patient care after EMR integration. Taking these results together, a conservative conclusion is that the patient quality of care did not decline after the EMR system integration between primary and specialist care institutions. This finding is important as EMR system implementations will impact clinical workflow processes, and it is essential to ensure that the integration does not unintentionally compromise the quality of care.

Finally, from the patient's perspective regarding care coordination post-EMR integration, our results show that they did experience shorter waiting times, as measured by the time required to schedule a specialist appointment. This quantitative finding was supported by the specialist clinic's perception of the improvements seen in managing referrals and appointment scheduling [19]. This perceived improvement, however, is less salient for the PCPs who did not perceive a significant improvement in appointment scheduling. From our interviews with the PCPs, we discovered that one of the reasons behind this finding was that their call center staff typically handle the appointment schedule for PCP referrals. As such, PCPs may not be aware about their patient's wait time to the next specialist appointment, which might explain their lack of perceived improvements post-EMR integration.

Comparison with Prior Work

This study is one of few studies that empirically quantifies the benefits of synchronizing the EMR systems between primary and specialist care to form a medical neighborhood. This contributes to the existing medical neighborhood literature as most of those studies were mainly advocating for the medical neighborhood through observational and logical deduction [3, 4, 9, 11] while our study provides empirical evidence to support the medical neighborhood framework.

Further, our research extends existing research in three key areas. First, prior studies that examined the referral integration between primary and specialized care institutions tend to study those where there is an asynchronous sharing of data between the PCPs and specialists [20] (i.e., the PCP provides patient medical data in their referral to the specialist, but the specialist does not share patient medical data back to the PCP, which prevents the co-management of the patient [9]). This asynchronous sharing is mainly due to the fact that the

referral systems used essentially functioned like messaging systems between primary and specialist care institutions and they did not involve a full EMR integration between primary and specialist care, which would have enabled the two-way referral information sharing [21]. Our investigation involved synchronous sharing and integration of medical records as part of referral integration, thereby permitting a closed referral loop.

Second, the outcomes of the integration of such referral systems are often mixed [22]. Some studies showed that integration reduced medical costs based on claims and fewer specialist visits [20]. Others found an increase in specialist referrals due to potentially tighter integration between primary and specialist care [23]. Regarding care coordination, referral systems were associated with poor information integration across stakeholders [24] but helped to improve wait time, communication, and administrative efficiencies [19]. Other studies suggested that the integration of EMR systems reduced unnecessary laboratory testing and imaging when previous test results are made available to referral specialists [25]. Many of these studies examined referral integration using a single data source and methodology, which presented a significant albeit limited view of integration. In contrast, our study provided a comprehensive examination of integration, showing concrete benefits by using multiple data sources to triangulate our results.

Third, most existing research relied on quantitative or qualitative indicators to examine referral and integration impacts. However, to properly assess the outcomes of EMR integration in PCMH-N, scholars have proposed that we should leverage on a mix of quantitative indicators (e.g. electronic tracking of referrals) and qualitative measures from clinician surveys and in-depth interviews (cf. Table 3[9]). Specifically, Greenberg et al. [9] called for a more holistic approach to measuring the performance of medical neighborhoods

using EMR data, along with surveying and interviewing clinicians. Likewise, Vimalananda et al.[13] suggested surveying clinicians to better understand what the success of such an implementation entails since the success of the medical neighborhood relies on the complicated alignment and coordination between PCPs and specialists [3]. We heed these calls for a more holistic assessment by employing a multi-methods approach in our research inquiry.

In sum, this work provides an initial step towards the validation of PCMH-N. The integration of EMR systems between primary and specialist care institutions is a necessary first step towards building a PCHH-N. Our literature review reveals that a comprehensive, empirical validation of the PCMH-N's benefits is relatively scarce, with those that are focused on parts of the PCMH-N having mixed results [20, 22, 23]. The seminal PCMH-N papers are commentaries or observational studies that logically argue for PCMH-N's benefits to public health and the management of healthcare resources [3, 4, 9]. Among the handful of studies that validated the PCMH-N's benefits are Tuot et'al.'s study [11] where they found that a feedback ratings system in an e-referral system created high-quality PCP-specialist pre-consultative engagement and virtual co-management of patients. Another study found that the use of an e-referral system for PCPs improved the ability to track referrals, reduced wait time for scheduled visits, and thereby improved patient access [26]. While these findings establish some aspects of the PCMH-N, they are based on asynchronous information sharing using an electronic messaging system and not through a fully integrated EMR system [12]. As such, many of the key benefits, like reduced repeat testing and imaging [25] and co-management [27] that could be delivered by the PCMH-N are still not extensively explored. Our study presents the findings of an integration that has fully synchronous medical data sharing across all institutions.

Limitations

As in all surveys and interviews, participation is voluntary. Though we have conducted an analysis and confirmed that early and late respondents have statistically similar responses, the possibility of respondent self-selection biases for the survey data exists.

Additionally, given the multi-method approach used in this study, the main purpose of the survey results is to triangulate the findings from the quantitative EMR data. The survey questions complemented the in-depth interviews. As a result, the questions used in the survey were not developed and validated in the typical comprehensive manner for survey scale development. The task of scale development can be a future study for researchers to embark on.

Conclusion

The aim of integrating the EMR systems of PCPs and specialists is to improve care and coordination continuity for a specific patient community. Such EMR integration of primary and specialist care institutions could improve patient diagnosis tracking, patient care management, and patient coordination. These improvements are manifested as tangible benefits such as reduced diagnostic redundancy, shorter patient wait time for specialist appointments, and lower patient bill sizes without compromising health outcomes. In this study, we analyzed specialist referral patient encounters and surveyed clinicians from primary and specialist care clinics to provide a set of comprehensive empirical evidence of integration benefits. We further triangulated our findings with in-depth interviews with the clinicians to better uncover the nuances of these benefits. Our results support the move towards integrating primary and specialist care EMR systems for a more efficient utilization of healthcare

resources, which will particularly benefit healthcare systems that face significant resource constraints.

Acknowledgment

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Appendix 1: STROBE – Methods & Results Reporting for Cohort Studies

Recommendation		Details
Methods		
Study design	Present key elements of study design early in the paper	Study design and setting presented in the paper
Setting	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	From 1 April 2020 to 31 March 2021, all patient encounters in various specialist care clinics within Ng Teng Fong General Hospitals, Singapore were referred from six primary care clinics.
Participants	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (b) For matched studies, give matching criteria and number of exposed and unexposed	Inclusion criteria: Specialist care encounters from the six primary care clinics between 1 April 2020 and 31 March 2021. Not applicable
Variables	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Outcome variables: 1. Patient wait time for specialist appointment 2. Number of procedure conducted at specialist clinic 3. Number of panel test conducted at specialist clinic 4. Number of lab tests conducted at specialist clinic 5. Number of X-rays conducted at specialist clinic 6. Bill size of the specialist encounter (normalized values for confidentiality reasons) 7. Binary flag to indicate if patient's ailment is resolved. Covariates (Control Variables): Medical specialty of the specialist clinic, the ICD-10 problem code, the procedure performed, the case's urgency as assessed by the primary care, the patient's gender, race, marital status, and visit date
Data sources/ measurement	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	The unit of data extracted is each patient encounter identified by a patient ID and encounter ID extracted from the electronic medical records from the EPIC system used by the healthcare institutions. All variables used in the analyses were obtained from these patient encounters.
Bias	Describe any efforts to address potential sources of bias	Given that the entire population of encounters was analysed, we do not expect any sampling bias for the patient encounter data. However, patient self-selection biases exist as we cannot analyze the difference between patients who select to go to these public healthcare institutions versus other patients who self-select into more costly private healthcare institutions. We recognize this as a limitation.
Study size	Explain how the study size was arrived at	The study size was a function of the selection of the time frame for the patient cohort. As we hope to examine the effects of EMR integration, we included

Appendix 1: STROBE – Methods & Results Reporting for Cohort Studies

		all specialist clinic encounters approximately six months before and six months after the EMR integration. Given all encounters were analyzed, the sample size is deemed to be sufficient prior to the data collection as the clinics typically get about 25,000 encounters referred to them from the primary care clinics within our sample.
Quantitative variables	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	We deliberately choose quantitative variables that were objective in this study for this cohort. All variables selected here captured the actual suite of activities that occurred during the patient encounter. We did not use any subjective measure for this particular dataset. In the estimation, we group (and flag) the patient encounters that occurred prior to the EMR integration as “pre” and those encounters after the integration as “post”. This allows us to quantify the changes associated with the integration.
Statistical methods	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	A total of six fixed-effects and six random-effects feasible generalized least squares regressions were run with the source of specialist care referral as the grouping variable (i.e., the source of each primary care clinic). These grouping will ensure that any primary care clinic difference can be controlled. These regressions were performed with outcome variables 1 to 6 (see Section “Variables” above). A separate fixed and a random-effects logistic regression were run with the binary outcome variable 7 (Section “Variable” above) To control for any confound the estimations involved using medical specialty of the specialist clinic, the ICD-10 problem code, the procedure performed, the case’s urgency as assessed by the primary care, the patient’s gender, race, marital status, and visit date as control variables. The objective of this study is not to examine the differences across the six primary care clinics. The study control for the potential difference of these clinics but did not observe any significant differences across them for our various key outcome variables. Missing data occurred for patient bookings where they did not come for the appointment (no-show) Unfortunately, patients who do not show up for the appointment are omission biases that cannot be measured. For each outcome variable to be examined, two models (one fixed-effects and one random-effects) were run. This ensures that the results obtained are consistent across different estimation modes.
Results		
Participants	(a) Report numbers of individuals at each stage of	25404 referral encounters were extracted and 22309 have complete data where the patient completed the

Appendix 1: STROBE – Methods & Results Reporting for Cohort Studies

	study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	consultation session. Patient no-shows for specialist appointments could be a result of seeking alternative treatment avenues. Data censoring only occurred at one stage, hence, we report these statistics as in line text instead.
Descriptive data	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	Refer to Table 2a within the manuscript A total of 22,309 encounters have complete data — 3,095 encounters do not have complete data as patients did not attend/ complete the specialist appointment that was referred to by the primary care health institution. It is not applicable as data is retrospectively collected from the electronic medical records.
Outcome data	Report numbers of outcome events or summary measures over time	Refer to Table 2b within the manuscript
Main results	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Refer to Table 3a, Table 3b in the manuscript. These estimates adjust for various confounds including: Medical specialty of the specialist clinic, the ICD-10 problem code, the procedure performed, the case's urgency as assessed by the primary care, the patient's gender, race, marital status, and visit date as well as the source of the referral. No continuous variables were categorized. Not applicable.
Other analyses	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable.

Appendix 2: COREQ– Consolidated criteria for reporting qualitative research

Domain 1: Research team and reflexivity

1. One author/researcher and a research associate conducted the interviews.
2. The author/researcher has a PhD in Business/Information Systems and the research associate has a Master in linguistics.
3. The author/researcher is an associate professor and a faculty in a business school and the research associate was employed as part of the research team.
4. The author/researcher is male while the research associate is female.
5. The author/researcher is trained in qualitative research methods while the research associate is trained in interview method.
6. The author/researcher and the research associate had no prior relationship with the interviewees
7. The participants/interviewees had no prior knowledge of the project.
8. The author/researchers had no specific bias or assumptions of the research topic. The author/researcher was invited to study the project by the project sponsors but had not vested interest in the project.

Domain 2: Study design

9. Framework: The study followed basic tenets of a grounded theory approach and was guided partly by the research question – which is the impact of the new EMR system on the referral process.

Participant selection:

10. Sampling: Interviewees were selected based on purposive sampling. We selected interviewees based on their roles and organizational units – we selected those who worked in the specific specialist clinics (chosen for the high volume of referrals received from the primary care clinics), the call center, and in specific primary care clinics (chosen for sending high number of referrals to the specialist clinics). Within those clinics and call center, we selected those who were held clinical and non-clinical roles and were involved in the referral process (from writing the referral, to processing, scheduling, and receiving the referrals). We wanted to have a diverse set of interviewees involved in the referral process.
11. Method of approach: We approached the interviewees via email – the hospital and clinic managers had endorsed our email invitation prior to sending the invitation to the interviewees.
12. Sample size and non-participation: We had 30 interviewees in our study.
13. Non-participation: There were no dropouts.

Setting

14. Setting: We conducted our interviews at the interviewees' office and via online Zoom.
15. Presence of non-participants: There nobody else present except for the interviewee and the researchers.
16. Description of sample: The key characteristic of the sample was their role in the referral process as described in the sampling approach.

Data collection

17. Interview guide: We developed a basic interview guide with a set of standardized interview questions. However, we allowed the interviewees to guide the interview depending on their responses and we did not strictly follow the guide.
18. Repeat interviews: We did not conduct any repeat interviews.
19. Audio recording: We recorded (with consent) the interviews. We did not collect any video recordings.
20. Field notes: We made field notes during and after the interviews.

Appendix 2: COREQ– Consolidated criteria for reporting qualitative research

- 21. Duration: Most of our interviews were about 30 minutes to an hour in duration.
- 22. Data Saturation: We did not discuss data saturation. We recruited as many interviewees as possible from the sites.
- 23. Transcripts: We did not return our transcripts for comment or correction.

Domain 3: Analysis and findings

- 24. Number of data coders: There were two data coders.
- 25. Description of coding tree: The coding structure was provided in the manuscript. We coded the data by organizational unit (primary care clinic vs. specialist clinic).
- 26. Themes: For each unit, we derived emergent themes from the data and we compared that with the data derived from other dataset (survey). The themes were thus derived from a combination of emergent data themes with the survey themes.
- 27. Software: We used MaxQDA (version 2020) to manage our data and data analysis.
- 28. Participant checking: We presented our narrative findings to the key stakeholders from the specialist clinic and primary care clinic for validation.
- 29. Quotations: We did present interviewee quotations to illustrate the themes and findings. Each quotation was identified by the title of the interviewee.
- 30. Data and findings: There was consistency in our data and findings.
- 31. Clarity of major themes: The major themes (“patient diagnosis tracking”, “patient coordination”, and “patient care management”) were presented in the findings.
- 32. Clarify of minor themes: There were no descriptions of diverse/minor cases or themes.

Supplementary Files

Untitled.

URL: <http://asset.jmir.pub/assets/be9ed5e6cf2b4b7741745b08376f81ad.doc>

Tracked changes.

URL: <http://asset.jmir.pub/assets/cff92df08f2f6c808e8df9d9a358b177.docx>

CONSORT (or other) checklists

Strobe checklist.

URL: <http://asset.jmir.pub/assets/697d6e7c3f1fe62e44e0567409bbf973.pdf>

COREQ checklist.

URL: <http://asset.jmir.pub/assets/fb743283d9b5aa81ccdb0e0e01798cb3.pdf>