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ORIGINAL ARTICLE

Application of an electronic Frailty Index in Australian primary care: data quality and feasibility assessment

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Abstract

Background The primary care setting is the ideal location for identifying the condition of frailty in older adults.

Aims The aim of this pragmatic study was twofold: (1) to identify data items to extract the data required for an electronic Frailty Index (eFI) from electronic health records (EHRs); and (2) test the ability of an eFI to accurately and feasibly identify frailty in older adults.

Methods In a rural South Australian primary care clinic, we derived an eFI from routinely collected EHRs using methodology described by Clegg et al. We assessed feasibility and accuracy of the eFI, including complexities in data extraction. The reference standard for comparison was Fried's frailty phenotype.

Results The mean (SD) age of participants was 80.2 (4.8) years, with 36 (60.0%) female ($n = 60$). Frailty prevalence was 21.7% by Fried's frailty phenotype, and 35.0% by eFI (scores > 0.21). When deriving the eFI, 85% of EHRs were perceived as easy or neutral difficulty to extract the required data from. Complexities in data extraction were present in EHRs of patients with multiple health problems and/or where the majority of data items were located other than on the patient's summary problem list.

Discussion This study demonstrated that it is entirely feasible to extract an eFI from routinely collected Australian primary care data. We have outlined a process for extracting an eFI from EHRs without needing to modify existing infrastructure. Results from this study can inform the development of automated eFIs, including which data items to best access data from.

Keywords Electronic health records · Frailty · Aged, 80 and over · Geriatric assessment · Primary health care

Introduction

The geriatric condition of frailty is recognised as a public health challenge, and is among the leading causes of mortality and morbidity in older adults [1]. Epidemiological studies have shown that frailty is present in around 3.5–27% of community-dwelling older adults, depending on the region and the measurement instrument used [2–5]. Frailty is a major barrier to independence in older adults, and is characterised by dysfunction across multiple organ systems that explains an increased vulnerability to external stressor events [1, 6].

A crucial step towards improving health service access and quality of life for older adults with frailty is early identification of the condition [4, 7, 8]. Primary care remains at the forefront of this identification [9–11]. Indeed, there is a plethora of frailty measurement tools that can be applied in primary care [5], although many of these require additional

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resources and time to complete, and hence are often used for research purposes rather than practice. Among these frailty measurement tools, Rockwood and Mitnitski's Frailty Index (FI) [12] stands out as a way to identify frailty using routinely collected primary care data—thereby eradicating the need to collect additional data. The FI incorporates the multidimensional nature of frailty into an operational definition. For instance, in a list of 30 or more health deficits (including co-morbidities, clinical symptoms, diseases and disabilities), the number of deficits an older person has is simply summed and then divided by the total number of deficits; the resulting ratio is the FI score, with a higher score indicating greater frailty [12].

Recently, Clegg et al. have devised an electronic Frailty Index (eFI) from primary care electronic health records (EHRs) in the UK [13]. Currently across the UK, an eFI is routinely used in primary care to identify older adults with frailty [13–15]. In the UK, it is relatively straightforward to derive an eFI in primary care, because general practitioners (GPs) list all patient diagnoses using SystmOne and EMISweb software [16, 17]. However, in many countries, eFIs may not be feasible to collect using routine EHRs for several reasons, including: variations in GP engagement; data capture and data quality between practices; as well as a high propensity to record GP notes as free (unstructured) text. Therefore, the aims of this study were to determine the feasibility and accuracy of extracting an eFI from routinely collected health information within the Australian primary care context. To translate the findings of this study into practice, a detailed analysis was performed to identify the data items to extract the necessary data.

Methods

Setting and participants

The study location was a single general practice site located approximately 2 h travel distance from metropolitan Adelaide within rural South Australia. We performed analysis on data drawn from a sub-sample of persons recruited for a diagnostic test accuracy study within the Australian general practice setting [18]. We selected the last 60 patients to be screened at the practice on a consecutive basis to minimise the time between screening and extraction of the EHR.

Eligible participants were: aged 75 years or older as on July 1, 2017; usual patients of the practice; had sufficient English proficiency to participate in the screening study; and not living within residential care or hospitalised at the time of data collection. Participants had given written informed consent for participation in the study, including permission to access their complete medical records. The Torrens University Higher Research Ethics Committee granted ethical approval for the eFI component of the study in January 2018. The study adhered to the Australian Code for the Responsible Conduct of Research. We followed the STARD (STAndards for Reporting Diagnostic accuracy studies) checklist.

Data collection

Participants had previously attended a face-to-face appointment at the general practice clinic between August 2017 and January 2018, where they completed a detailed questionnaire incorporating demographic variables (age, sex, living arrangements), and several administered frailty screening instruments along with an internationally accepted frailty reference standard by a trained practice nurse and the first author, respectively (see details below). Subsequent to the conclusion of their appointment, the practice nurse extracted the EHR against a pre-defined template during February 2018 [19] using the general practice software programme Zedmed version 28.3. The mean (SD) time elapsed between the screening appointment and extraction of the eFI data was 92.4 (20.1) days; the range was 49–121 days. The nurse was blinded to the reference standard (Fried's frailty phenotype) results when extracting the eFI data.

Frailty measurement instruments

The reference standard was the Fried's Frailty Phenotype as developed for the Cardiovascular Health Study (CHS) [20]. As per Fried's phenotype, shrinking was measured by unintentional weight loss of 10 pounds or greater in the previous year; weakness was measured by grip strength less than the relevant CHS cut-points for men and women; exhaustion was measured through self-report and was based on the Center for Epidemiological Studies-Depression (CES-D) scale; and slowness was measured by CHS cut-points for time taken to walk 15 ft [20]. The key modification to the original Fried phenotype was in the use of the Physical Activity Scale for the Elderly (PASE) [21] in substitute for the complex Minnesota Leisure Time Activity questionnaire [22] to measure low physical activity, as has been applied in previous research [23]. The Paffenbarger Score (62) was used to convert self-reported PASE activity to an estimate of kilocalories expended per week, with the same cut-offs as specified in the CHS study subsequently applied. Participants were classified as frail if they scored positively on at least three of the five CHS criteria.

The eFI model applied in our study was originally specified in the UK by Clegg et al. [17] and is a 36-item FI [24] including variables based on Clinical Terms Version 3 (CTV3) Read codes [17]. Data items included chronic conditions, polypharmacy (5 + prescribed medications) and social isolation. In our application of the model, participants

were classified frail if they scored > 0.21 on the eFI, following a threshold established in previous research [25].

Due to expected differences between the UK and Australian general practice contexts, the practice nurse at our research site conducted a preliminary review of the 36-item list against a typical patient record within the Zedmed practice software programme to inform the development of the data collection template. Based on this information, we developed a template for data collection incorporating the eFI items listed against the source of the data: either the Problem List, a patient summary based on the patient's previous presenting issues or an "Other" category incorporating other potential sources of data including GP notes (free text), medication history, clinical results, care plans, assessments and letters from specialists. Where the source was "Other", the nurse was requested to specify the source.

Feasibility measures

Feasibility data collected included time taken to extract the data (minutes), ease of completion (a five-item Likert scale ranging from Very Difficult to Very Easy), and an option to capture free text commentary regarding feasibility of extraction.

Data analysis methods

Descriptive statistics were used to describe the sample at baseline. Efficacy measurements included specificity, sensitivity, positive predictive value and negative predictive value for the eFI against the Fried Phenotype, along with the 95% confidence intervals. Second, we conducted an auROC (area under the receiver operating characteristic curve) analysis, comparing the auROC curves between the Phenotype and the eFI. The higher the auROC value, the better the discriminative ability, up to a maximum possible score of 1.0. Cohen's kappa was also computed to indicate degree of agreement. All analyses were performed using SPSS version 25.0 (SPSS Inc, Chicago, Illinois) and Microsoft Excel 2016 (Microsoft Corporation).

Results

Selected characteristics of the participants are shown in Table 1. The mean (SD) age of participants upon attendance at the screening appointment was 80.2 (4.8) years, and 36 (60.0%) were female. As classified by the Fried Phenotype criteria, 12 (20.0%) were robust; 35 (58.3%) were pre-frail and 13 (21.7%) were frail.

By the eFI, 21 (35.0%) participants were frail, which indicated a sensitivity of 84.6% (95% CI 54.6–98.1) and specificity of 78.7% (95% CI 64.3–89.3) ("Appendix"). The maximum score of the eFI was 0.36. The positive likelihood ratio was 3.98 (95% CI 2.19–7.22) and the negative likelihood ratio was 0.20 (95% CI 0.05–0.71). Observed agreement between the instruments was deemed moderate as measured by the kappa statistic (80% agreement in observations, kappa = 0.52, 95% CI 0.29–0.75). The eFI returned an auROC value of 0.900 (Fig. 1), indicating a high level of accuracy in identifying frailty.

The most commonly identified variable for the eFI was hypertension ($n = 48$; 80.0%), followed by arthritis ($n = 40$; 66.7%), polypharmacy ($n = 39$, 65.0%), diabetes ($n = 26$, 43.3%), urinary system disorders ($n = 19$; 31.7%), dizziness ($n = 18$, 30.0%), anaemia ($n = 14$, 23.3%) and osteoporosis ($n = 14$, 23.3%). In contrast, variables with low (less than 5) or no results recorded included chronic kidney disease (CKD), fragility fracture, heart failure, housebound, hypotension, memory and cognitive problems, peripheral vascular disease, social vulnerability and weight loss/anorexia.

Feasibility

There was significant variation with respect to time taken to extract the required data items for the eFI. There was a moderate positive correlation between time (minutes) and the

Table 1 Patient characteristics according to frailty status (fried phenotype): $n = 60$

Characteristics	Robust ($n = 12$)	Pre-frail ($n = 35$)	Frail ($n = 13$)
Female, *n* (%)	10 (83.3)	17 (48.6)	9 (69.2)
Age, mean (SD)	77.4 (2.5)	79.8 (4.5)	83.7 (5.6)
Living Alone, *n* (%)	6 (50.0)	9 (25.7)	7 (53.8)
Polypharmacy (5 + medications)[a], *n* (%)	4 (33.3)	22 (62.9)	13 (100.0)
Chronic conditions[a], *n* (%)			
Hypertension	10 (83.3)	27 (77.1)	11 (84.6)
Arthritis	6 (50.0)	24 (68.6)	10 (76.9)
Diabetes	4 (33.3)	15 (42.9)	7 (53.8)

[a]Obtained from medical record

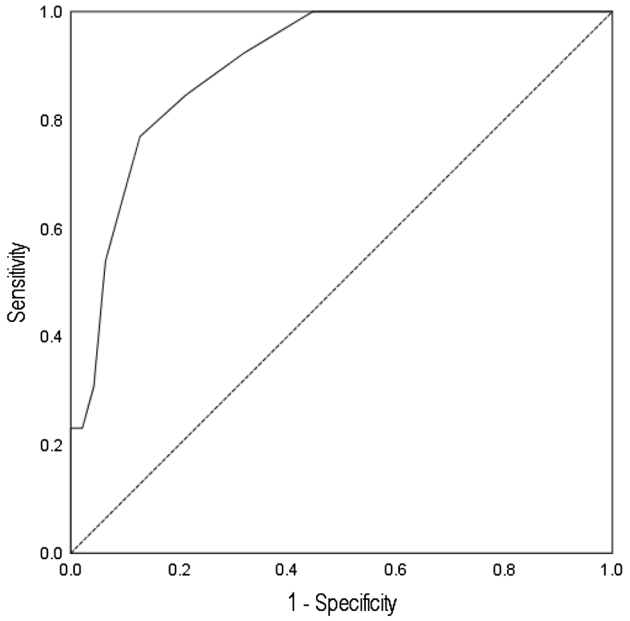

Fig. 1 Receiver operator curve: eFI against fried phenotype. Total area under curve (AUC) = 0.900 ($P < 0.001$)

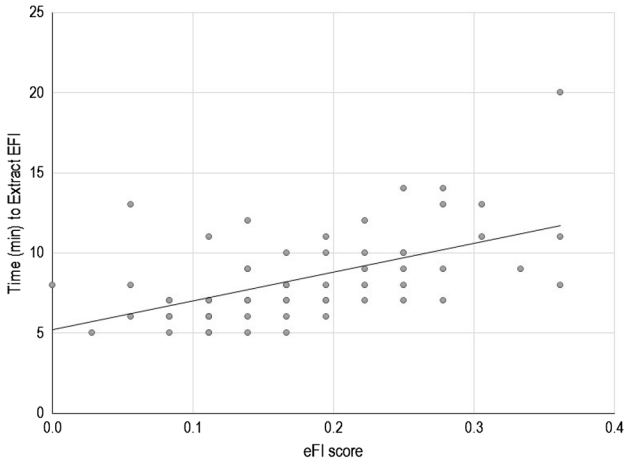

Fig. 2 Time taken to extract eFI items vs. eFI score of patient ($n = 60$)

eFI score, ($r = 0.54$, $P = < 0.01$), indicating that the higher the frailty score, the longer it took to extract the data from the record. The median extraction time per record was 8 min (range 5–20 min). Almost half of all records ($n = 27$, 45.0%) were deemed easy to extract, with a further 40% ($n = 24$) perceived to be of neutral difficulty. In contrast, 15% ($n = 9$) were judged difficult to extract. Most commonly, the eFI data were perceived as difficult to extract when there were either many problems listed within the patient record, and/or where the majority of items were located other than on the summary problem list for the patient, as indicated by free text commentary entered by the nurse. Table 2 shows the frequency of individual items recorded in the eFI against the source of data. In general, eFI items based on chronic conditions were readily found in the presenting problems list, while other items such as polypharmacy, activity limitation, falls and mobility limitations were found elsewhere (medication tab, care plan documentation, free text commentary) (Fig. 2).

Discussion

Results from this exploratory study indicated that it is entirely possible and certainly feasible to manually derive an eFI from routine patient medical records in an Australian primary care practice. This study also outlined a process for extracting eFI data from Australian primary care EHRs without the need to modify any existing infrastructure, including which data items were optimal against the eFI model reported by Clegg et al. [17]. Overall, 85% of EHRs in our dataset were perceived as easy or of neutral difficulty to extract the required items to complete the index. Closer inspection of EHRs perceived as difficult to extract data items from revealed that these typically belonged to patients with complex co-morbidities.

Although the concept of using EHRs to derive an FI is not new [14], our study is unique in that we independently assessed the diagnostic accuracy of our eFI against a well-established frailty measurement instrument: Fried's frailty phenotype [20]. The eFI showed high discriminative ability (auROC = 0.900); against Fried's frailty phenotype; a value higher than the majority of international literature comparing the phenotype with an FI [5, 26, 27]. These results are particularly notable given that the FI and Fried's phenotype are based on different theoretical frameworks. Our high value could be because of the high efficacy of the eFI against Fried's phenotype, it could reflect the fact that we had no individuals with low cognition in our sample, or alternatively that Clegg's eFI formulation [17] tends to focus on chronic conditions rather than social health and well-being.

We also note that the maximum score obtained by our eFI (0.36) was not especially high in comparison with previous research; for example, none of our patients were found to be severely frail (> 0.36) in contrast to two UK general practice samples recording approximately 12% prevalence in this category [15, 28]. This discrepancy may be due to a number of factors: our study adopted a manual search rather than an automated process; our participants were not supported to attend their appointment though provision of transport, thus resulting in a potentially healthier sample; or to differences in data collection practices between the two study contexts.

The most frequently recorded items in our eFI were hypertension, arthritis, polypharmacy, and diabetes. In contrast, many items such as social vulnerability, housebound,

Table 2 Frequency of individual items recorded in the eFI ($n = 60$) against source of data

Variables	*n* (%)	Percentage from problem list[a] (%)	Percentage from other data source[c] (%)
Activity limitation	10 (16.7)	30.0	70.0
Anaemia and haematinic deficiency	14 (23.3)	50.0	57.1
Arthritis	40 (66.7)	72.5	22.5
Atrial fibrillation	11 (18.3)	100.0	0.0
Cerebrovascular disease	8 (13.3)	75.0	25.0
Diabetes	26 (43.3)	96.2	3.9
Dizziness	18 (30.0)	38.9	61.1
Dyspnoea	12 (20.0)	25.0	83.3
Falls	11 (18.3)	9.1	90.9
Foot problems	8 (13.3)	75.0	25.0
Hearing impairment	10 (16.7)	100.0	0.0
Heart valve disease	5 (8.3)	100.0	0.0
Hypertension	48 (80.0)	97.9	0.0
Ischaemic heart disease	10 (16.7)	100.0	0.0
Mobility and transfer problems	9 (15.0)	33.3	55.6
Osteoporosis	14 (23.3)	71.4	28.6
Peripheral vascular disease	0 (0.0)	n.a	n.a
Polypharmacy	39 (65.0)	2.6	97.4
Requirement for care	7 (11.7)	0.0	100.0
Respiratory disease	9 (15.0)	100.0	0.0
Skin ulcer	6 (10.0)	16.7	66.7
Sleep disturbance	12 (20.0)	50.0	50.0
Social vulnerability	0 (0.0)	n.a	n.a
Thyroid disease	10 (16.7)	90.0	10.0
Urinary incontinence	5 (8.3)	80.0	20.0
Urinary system disease	19 (31.7)	100.0	0.0
Visual impairment	12 (20.0)	91.7	8.3
Weight loss and anorexia	0 (0.0)	n.a	n.a
Chronic kidney disease, fragility fracture, heart failure, housebound, hypotension/syncope, memory and cognitive problems, Parkinsonism and tremor, peptic ulcer	[b] ([b])	n.a	n.a

[a]Totals may not add to 100% where item is present in both Problem List and Other or where source is missing

[b]*n* suppressed for these cases due to confidentiality; n = between 1 and 4 for each condition

[c]Other source = GP notes (free text), medication history, clinical results, care plans, assessments and letters from specialists

peripheral vascular disease were found only infrequently or not at all within patient EHRs. However, a key point for consideration in future studies is the extent to which a coding of "no deficit" for any individual data item truly reflects that the patient does not have the condition. There are a number of reasons why a deficit might not be coded even where the patient has the condition. These include human error at either point of data entry or extraction, lag in record update after attendance and undiagnosed conditions. It could also be that HSPs find it more difficult to record more abstract concepts such as 'social vulnerability' rather than chronic conditions based on ICD-10 codes. These considerations have implications for potential automation of the eFI, a process which may need to rely more on presenting problems rather than free text- or PDF-based data items. Consequently, it might be that alternative items such as depression, which can be more readily identified in a presenting problems list, may be more suitable for inclusion in an eFI than some specified in the original formulation.

The extraction process presented in this study was manual, yet it provides a critical foundation to guide development of automated eFIs from primary care EHRs in Australia and other countries with similar primary care systems. However, there is still much progress to be made before reaching a level of sophistication comparable with the UK. One of the key barriers remains the fact that, as private

providers of health care, Australian GPs are the custodians of their own practice data, and so there is significant variability with respect to data quality [29]. These factors have significant implications for the time and effort required to routinely generate eFIs, as it implies a practice-by-practice (or group of practices) proposition, rather than a large-scale operation capable of being run efficiently across a central database. A further potential barrier to widespread implementation of eFIs in Australia, as per many other countries, is the lack of interoperability of medical software between practices [30–32]. If these systems cannot inter-operate, this poses a major barrier to linking eFIs nationally for the purposes of informing public health practice. Consequently, the feasibility of deriving an eFI from EHRs may vary substantially between practices and our results may not be generalizable across all primary care practices with EHRs. Notwithstanding this, with the rapid advancements in e-Health, this barrier is only expected to be relatively short term.

Identifying older adults with frailty is advantageous for many reasons. Primary care is where patients start to present with minor issues, which taken together do not mean anything significant, but when combined together to form a FI, may indicate early frailty development. Further, given the complex and time-pressured nature of most primary care settings, the comprehensive indication of patient condition indicated by the FI could work to support a holistic and person-centred approach to care. In addition, the potential application of the FI need not be restricted to purposes of identifying and treating frailty. For instance, identifying different combinations of health deficits could serve many different purposes, such as case-finding patients with specific complex care needs. Detecting a patient as frail or pre-frail using an eFI has many benefits for the older patient, including targeted fall prevention strategies, and referral to comprehensive geriatric assessment clinics. We note that in doing so, identifying frailty is by no means meant to discriminate against the older adult living with frailty, but rather to inform their care and avoid any unnecessary harm [4].

In the present study, we found that some items were not often in the main summary sheet, including polypharmacy, activity limitation, falls and mobility limitations. This finding could have important implications for the applicability and relevance of an eFI in primary care records given previous research which has found that these health deficits occur as a common co-morbid pattern among older adults with frailty [33]. Moreover, the relatively inaccessible location of these items for coding within the EHR, paralleled with inconsistent coding practices, means that they may be frequently missed in the generation of automated eFIs.

The present study had multiple advantages, including the ability of our eFI to utilise data routinely collected from a primary care service without needing to modify any infrastructure. A further advantage is that we were able to assess the diagnostic accuracy of the eFI against Fried's frailty phenotype as conducted by an independent, trained researcher. Despite these advantages, the present study also showed several limitations. First, we did not impose any requirements on the recency of the information held within the EHR; it is, therefore, possible that some of the information included may have been out of date (for example, in the case of a reversal of a chronic condition such as diabetes or where a patient has stopped taking a certain medication). Second, the sample size was small, and the feasibility across other primary care practices in a larger-scale dataset needs to be determined. Third, in generating the eFI, we have assumed that patient records accurately reflect the patient's diagnoses, and thus their frailty status. However, it is clear from previous research that many conditions remain undiagnosed [34]. Finally, the feasibility data were generated by a single practice nurse using a particular medical software system; it is possible that reported feasibility may vary significantly if tested within a more heterogeneous group of nurses or if applied to other software. Nonetheless, the very high degree of sensitivity indicated within the results suggests generation of the eFI is a highly promising option, especially where it is known that practices are active in maintaining the quality of their patient databases.

A number of major improvements are needed within the Australian context before widespread uptake of an eFI could become a reality. These include: better public and health service provider awareness about frailty and its consequences; health system change at all tiers of government including a shift away from crisis management of frailty towards proactive, person-centred care; and the provision of policy and funding incentives for primary care practices to support identification and treatment of frailty. Taken together, these changes would create the momentum necessary to ready the health care system to provide better outcomes for older people at risk of or living with frailty.

Conclusion

This exploratory study has presented results suggesting a highly sensitive method for routinely identifying frailty within patient EHRs within Australia, indicating high potential feasibility for broader implementation within general practice. The process profiled in this study for extraction of an eFI from routine patient EHRs may prove valuable to practices seeking to assess the frailty status of their older patients in a systematic manner. However, further research is needed to ascertain how generalizable these results are

to other contexts, especially with regard to those using different medical software systems or in circumstances where data quality is variable. Ultimately, true automation of this process would require the support of a data extraction tool such as those currently applied to other conditions, or alternatively the development of a purpose-built tool to be integrated within existing software. As such developments can be significantly time and resource intensive, it may yet be some time before Australia approximates the current level of progress of more advanced nations with respect to eFI implementation.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Statement of human and animal rights This study received ethics approval from the Torrens University HREC Committee (#H1/18) and was conducted in accordance with the Declaration of Helsinki.

Informed consent Informed consent was obtained from all individual participants included in the study.

Appendix

See Table 3.

Table 3 Comparison of frailty status according to eFI and phenotype

	Fried Phenotype		
	Frail	Not frail[a]	Total
eFI			
Frail	11	10	21
Not frail	2	37	39
Total	13	47	60

[a]Robust and pre-frail participants

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