Identifying patterns of health care utilisation among physical elder abuse victims using Medicare data and legally adjudicated cases: protocol for case-control study using data linkage and machine learning

Tony Rosen,1 Yuhua Bao,2 Yiye Zhang,2 Sunday Clark,1 Katherine Wen,3 Alyssa Elman,1 Philip Jeng,2 Elizabeth Bloemen,4 Daniel Lindberg,5 Richard Krugman,5 Jacquelyn Campbell,6 Ronet Bachman,7 Terry Fulmer,8 Karl Pillemer,3 Mark Lachs9

ABSTRACT

Introduction Physical elder abuse is common and has serious health consequences but is under-recognised and under-reported. As assessment by healthcare providers may represent the only contact outside family for many older adults, clinicians have a unique opportunity to identify suspected abuse and initiate intervention. Preliminary research suggests elder abuse victims may have different patterns of healthcare utilisation than other older adults, with increased rates of emergency department use, hospitalisation and nursing home placement. Little is known, however, about the patterns of this increased utilisation and associated costs. To help fill this gap, we describe here the protocol for a study exploring patterns of healthcare utilisation and associated costs for known physical elder abuse victims compared with non-victims.

Methods and analysis We hypothesise that various aspects of healthcare utilisation are differentially affected by physical elder abuse victimisation, increasing ED-hospital utilisation and reducing outpatient/primary care utilisation. We will obtain Medicare claims data for a series of well-characterised, legally adjudicated cases of physical elder abuse to examine victims’ healthcare utilisation before and after the date of abuse detection. We will also compare these physical elder abuse victims to a matched comparison group of non-victimised older adults using Medicare claims. We will use machine learning approaches to extend our ability to identify patterns suggestive of potential physical elder abuse exposure. Describing unique patterns and associated costs of healthcare utilisation among elder abuse victims may improve the ability of healthcare providers to identify and, ultimately, intervene and prevent victimisation.

Ethics and dissemination This project has been reviewed and approved by the Weill Cornell Medicine Institutional Review Board, protocol #1807019417, with initial approval on 1 August 2018. We aim to disseminate our results in peer-reviewed journals at national and international conferences and among interested patient groups and the public.

INTRODUCTION

Elder abuse is common and has serious health consequences but is under-recognised and under-reported. As many as 10% of US older adults experience elder abuse each year.1 4 6 This maltreatment may include...
physical abuse, sexual abuse, neglect, psychological abuse or financial exploitation, and many victims suffer from multiple types of abuse concurrently.1-3 Evidence suggests that elder abuse is associated with adverse health outcomes, including disability,7 dementia,8 depression1 and mortality.9-11 Despite its frequency, many elder abuse victims endure it for years before having it discovered or dying. Studies suggest that as few as 1 in 24 cases of elder abuse is reported to the authorities,13 and some of the associated morbidity and mortality is likely due to this delay in identification and intervention.13

As assessment by healthcare providers may represent the only outside contact for many older adults, so clinicians have a unique opportunity to identify suspected elder abuse and initiate intervention.14-20 Elder abuse victims have increased rates of emergency department (ED) use,14 17 hospitalisation21 and nursing home placement.22 23 Little is known, however, about the patterns of this increased utilisation and associated costs.5 24 Influential research in child abuse25-30 and intimate partner violence31 32 has focused on healthcare utilisation before identification, highlighting that many victims had multiple previous visits for likely abuse-related issues, suggesting ‘missed opportunities’ for identification and early intervention. Child abuse researchers have found that minor abusive injuries, ‘sentinel injuries’, are commonly found in children who are subsequently victims of severe child abuse but rare in those who are not.33 34 Strategies are being developed to capitalise on these findings to prevent morbidity and mortality for victims. Additionally, research has found that healthcare costs were significantly higher for victims of child abuse and intimate partner violence both in the short term35 36 and long term35 37-40 compared with costs incurred by non-victims. These increased costs represent a key component of the overall economic burden of these phenomena,41-44 and related research findings have been critical in revealing the scope and impact of child abuse and intimate partner violence and in driving policymaking decisions. We know of no analogous research in elder abuse.

To help fill this gap in the literature, we describe here the protocol for a study designed to explore in detail patterns of healthcare utilisation and associated costs for known physical elder abuse victims compared with non-victims using analytic techniques including machine learning.

METHODS AND ANALYSIS
Conceptual framework and hypotheses
We hypothesise that various aspects of healthcare utilisation are differentially affected by physical elder abuse victimisation. Many issues related to physical elder abuse potentially increase ED/hospital utilisation and reduce outpatient/primary care utilisation. We have developed a conceptual framework (figure 1) to explain this pattern. This framework is informed by a model for elder abuse research that members of our team developed as part of the National Institutes of Health Workshop ‘Multiple Approaches to Understanding and Preventing Elder Abuse and Mistreatment: Prevention and Intervention’.45

As shown in figure 1, we further hypothesise that physical elder abuse victims, due to their poor connection to primary care, will have increased utilisation of EDs/hospitals for ambulatory care-sensitive conditions (ACSCs) and for non-urgent issues. ACSCs are conditions that, if treated in a timely fashion with adequate primary care and managed properly on an outpatient basis, should not

Figure 1  Conceptual framework for healthcare utilisation by elder abuse victims. EDs, emergency departments.
advance to the point where an ED visit or hospitalisation is required. We measured the rate of use of high-intensity, high-cost services to treat these conditions is common in health services research to assess access to and quality of primary care. Similarly, use of the ED for non-urgent issues suggests inappropriate use in the absence of primary care.

We also hypothesise that physical elder abuse victims will have high rates of repeat ED visits and rehospitalisations within short intervals. This results from poor connections to primary care and poor adherence to outpatient follow-up care recommendations. We anticipate that physical elder abuse victims will also have higher use of the ED/hospital for issues directly related to abuse, including presentation for injuries and use of imaging to evaluate specific injury types. Based on anecdotal experiences by elder abuse experts, we also hypothesise that, compared with other older adults, physical elder abuse victims will more likely be seen at multiple EDs and hospitals. This ‘hospital hopping’ often occurs to avoid abuse detection.

Conversely, we hypothesise that poor access to and less frequent use of primary care will be associated with more primary care provider changes, lower receipt of preventative services and worse continuity of care. More frequent changes in primary care providers result in fractured care and have been shown in previous claims-based research to be associated with child abuse. Receipt of preventative services has been used in previous studies to assess level of primary care utilisation among Medicare beneficiaries and has been shown to be lower in older adults with lower primary care access including excess alcohol use and poor health literacy. We anticipate that physical elder abuse victims will have lower continuity of care, which has been shown in Medicare beneficiaries to be associated with increased rates of frequent ED use. Continuity of care assesses the dispersion of outpatient evaluation and management visits, examining how many unique doctors a patient visits within a specific timeframe.

Finally, we also hypothesise that victims of physical elder abuse, partially due to poor connection to primary care, will have poorer adherence to medications for chronic conditions, such as diabetes medications and antihypertensives, which has been shown to impact high-intensity healthcare utilisation and cost.

Study design
In this retrospective study, we will obtain Medicare claims data for a series of legally adjudicated cases of physical elder abuse to comprehensively examine victims’ healthcare utilisation before and after the date of abuse detection. We will also compare physical elder abuse victims to other non-victimised older adults. We will algorithmically select this comparison group from Medicare claims data to be matched to the physical elder abuse victims.

We will compare victims’ ED/hospital and outpatient primary care utilisation to that of the control groups. We will use machine learning approaches to extend our ability to identify patterns suggestive of potential physical elder abuse exposure.

This project has been reviewed and approved by the Weill Cornell Medicine Institutional Review Board, protocol #1807019417 (initially approved on 1 August 2018). The Institutional Review Board approved waiving the requirement to obtain informed consent from subjects in this retrospective study.

Study subjects
For this research, we plan to use a well-characterised series of 204 legally adjudicated cases of physical elder abuse from Brooklyn, New York, and Seattle, Washington. The methodological advantage of this series of cases is unique: because the perpetrators have pled guilty or been convicted, the presence of elder abuse has been verified and the time of detection is known. This dataset includes rich information about the abuse victims and perpetrators as well as details about the abuse history, when and how it was detected, and the surrounding circumstances. It was constructed using information from the legal case files, including: medical records, descriptions of emergency medical services personnel and police interactions with the victim and perpetrator, victim statements, adult protective services files, court documents and photographs of injuries.

Medicare data linkage
We will link these legally adjudicated cases to Medicare claims data using identifying information including social security numbers and/or a combination of last name, date of birth and residential ZIP code. Fee-for-service Medicare data are the largest single repository of patient healthcare data for US older adults, offering comprehensive information on utilisation of a broad range of healthcare services for continuously enrolled individuals. Medicare claims data have been used successfully to analyse healthcare utilisation and costs and to inform interventions and policies for a variety of chronic diseases. Additionally, claims data have been used to examine the impact on utilisation and cost of sociomedical issues including excessive alcohol use. Medicare claims data have also been employed to provide insight into the characteristics of frequent users of specific health services, such as the ED and hospital.

We plan to examine Medicare claims data for each case from 3 years before to 3 years after detection of elder abuse and will compare with controls. We will use files including: the Master Beneficiary Summary File (enrollee demographics, monthly enrolment information, chronic conditions, annual summary of costs and service utilisation), Medicare Provider Analysis and Review file (events of inpatient hospital and skilled nursing facility stays), Outpatient Claims, Carrier File (claims of physician services), Home Health Claims and the Part D (prescription drug) Event File.

Measures
We describe the key measures of utilisation we plan to use in table 1. We intend to focus primarily on utilisation of
high-intensity, high-cost healthcare services including ED visits and hospitalisations by elder abuse victims and non-victim control subjects. We will examine overall utilisation of these services and will also look at several characteristics of this utilisation. We will examine the frequency of ED use and hospitalisation among victims and compare utilisation of these services of victims and non-victim controls. We will focus on injury-related utilisation, using ICD codes and external cause of injury codes similar to previous work in child abuse. We will also examine frequent ED use, defined as four or more visits in a year, the cut-off accepted in the literature and used in previous Medicare research. We plan to measure the number of potentially avoidable low-urgency ED visits as well as ED visits and hospitalisations for ACSCs. We will define low urgency visits similar to previous literature using Medicare Current Procedural Terminology billing codes (99281 and 99282) indicating low severity and no additional procedures billed. For this research, we will use the 11 ACSCs established for use in Medicare data. We will also examine repeat ED visits and hospitalisations within short intervals. Consistent with previous research, we will examine visits to the ED within 3 days, 7 days and 30 days of initial visit as well as repeat hospitalisations within 30 days and 90 days of initial hospitalisation. Additionally, we will explore use of multiple EDs and hospitals.

For outpatient care, we will examine the number of primary care visits and focus on injury-related visits for victims and controls. We will also examine changes in primary care providers. We plan to evaluate the continuity of care using the widely employed Continuity of Care Index (COCI). Given that the COCI requires multiple outpatient visits to be meaningfully calculated, we will only examine this variable for subjects with three or more outpatient visits, consistent with previous literature. We will measure whether physical elder abuse victims and control subjects received preventative services, including influenza vaccination, glaucoma screening, pneumonia vaccination and mammogram. We plan to examine adherence to medication for chronic conditions. To do this, we will measure the proportion of days covered and determine adherent versus non-adherent using 0.80 as a cut-off, a common research strategy in administrative claims data.

We will examine demographic data, including age, gender and race/ethnicity. We will also use claims data for key health-related covariates to allow for further characterisation of physical elder abuse victims and comparison of subgroups. These include medical comorbidities, psychiatric comorbidities, dementia and frailty. For medical comorbidities, we plan to use chronic condition indicators within the Medicare Master Beneficiary file, and we will use psychiatric diagnoses within claims data. We will use an established approach to identify dementia. To identify frailty, we will use a recently developed algorithm designed for use in Medicare claims data.

### Non-victim control subjects

We will select a group of non-victim control subjects matched to the cases on age, race, gender and residential zip code at the time of detection of each elder abuse case. This control group will allow us to compare healthcare utilisation of elder abuse victims with that of a general older adult population. We will construct a second control group who, in addition to being matched to the cases on age, race, gender and ZIP code, visited the ED for an unintentional injury within 1 week of the victim’s abuse detection by law enforcement. This second control group will allow us to explore potential differences between older adults presenting to the ED for abuse-related injuries and those presenting with unintentional injuries, a key focus of our previous research.

Findings
from such comparisons may assist healthcare providers, particularly in the ED, to differentiate between physical elder abuse and unintentional injuries, informing future development of clinical algorithms to assist in this identification. Because we may have more controls than needed meeting the selection criteria within the first control cohort outlined above, we will further conduct propensity score matching to select controls that more closely match with the cases.

We recognise that older adults selected as control subjects may actually be victims of physical elder abuse. To minimise the likelihood of this, we will ensure that all selected controls have never received any elder maltreatment-related diagnosis within Medicare claims data.

Focus on physical abuse

Though physical elder abuse may occur less frequently than other types of mistreatment, we think that focusing on these cases is a strength of our approach. Researchers have recognised that elder mistreatment is not a monolithic phenomenon and that aetiologies, victim and perpetrator characteristics, risk factors, clinical features and sequelae likely differ in important ways between mistreatment types. An important reason that previous research has yielded inconsistent findings and little clinically useful information is likely that heterogeneous cases were analysed together. We have chosen to focus on physical abuse because this violent mistreatment may be particularly dangerous for an older adult. Our research focuses on healthcare utilisation for abuse victims and the potential for improving early identification in healthcare settings such as the ED. Given that physical abuse often causes acute injury that may trigger healthcare visits more commonly than other types of elder mistreatment, healthcare providers may have a particular opportunity to identify it. Linking known elder abuse cases to Medicare claims data to describe rates and patterns of healthcare utilisation may also be used to examine victims of other types of elder mistreatment though, and we plan to explore this in the future.

Analysis

We will conduct descriptive longitudinal analysis of healthcare utilisation up to 3 years before and 3 years after the detection of elder abuse (and among control cohorts). For each elder abuse case, we will determine the calendar month in which the case was detected (the ‘index month’). We will then group months before and after the index month into 3-month intervals/quarters. Our unit of analysis will be patient-quarter. We will plot measured outcomes over time (centred around the index month) and visualise level of utilisation in time blocks in relationship to the index month.

We will compare utilisation between physical elder abuse cases and non-victim control subjects using the key measures described above, focusing on identifying important differences. Comparisons will also specifically focus on rates of radiographic utilisation of maxillofacial CT scan and forearm X-rays as well as diagnoses including acute or chronic facial or chronic ulnar fracture, and chronic rib fracture as they have been found to be potential predictors of physical elder abuse. We will compare total costs between cases and controls and then examine in detail contributing costs associated with each type of utilisation.

We will also conduct statistical modelling of longitudinal healthcare utilisation outcomes to estimate adjusted differences between physical elder abuse victims and non-victims at various time points before and after the index month. For example, for the dichotomous outcome of any ED or inpatient admission in a quarter, we will estimate a mixed logistic regression where major covariates include victim status, time (relative to index month) and interaction of victim status and time, controlling for individual demographics and comorbidities. Random effects will be specified at the patient level (to account for repeated measures of the same individual) and zip code (to account for clustering of patients within the same zip code) levels.

We have conducted power calculations with these cases and controls, incorporating assumptions about Medicare linking rate (50% of cases), number of quarters of data contributed by each individual (six quarters), percentage of subjects with ≥1 ED visit in a quarter (12% of elder abuse victims and 6% of controls) and intrachannel correlation (0.2, to account for clustering of quarters within the same individual). Using these assumptions, we have a power of 0.82, which is adequate to identify important differences in utilisation between cases and controls.

Using machine learning

The comparative statistical analysis described above will illuminate the trajectories of healthcare use one type at a time. It lacks the ability to integrate multidimensional data that, combined, forms unique patterns of care. Recent innovations in machine learning make it possible to use vast amounts of data, such as service utilisation, diagnoses received and procedures performed, to identify sequences and mix of clinical events likely to lead to particular outcomes or suggestive of an underlying disease process for different cohorts of patients.

For example, sequential pattern mining has been used in child abuse to examine patterns of services provided to victims. To supplement the proposed statistical analysis, we propose to search for features within claims data that may be suggestive that an older adult is a victim of abuse. We will use Sequential Pattern Discovery using Equivalence classes, a well-established algorithm that identifies patterns that are observed more than a user-defined frequency threshold in a cohorts’ sequences of event. In addition, we will use Markov modelling to identify the probabilities of observed patterns and associated underlying status of abuse to better distinguish patterns that are unique to elderly abused patients. We may find, for example, that a significant percentage of
abuse victims have two ED visits and a hospitalisation within a 3-month period and receive forearm X-rays and are diagnosed with a fracture, but this pattern is never seen in controls.

**Patient and public involvement**

We plan to involve older adults including victims of elder mistreatment in the reporting and dissemination for this research.

**Timeline**

This research was initiated in 2018, and we plan to report results by 2023.

**Discussion**

This ongoing work will address a significant gap in current knowledge about elder abuse by improving understanding of how physical abuse victims use healthcare services differently than non-victims as well as associated costs. We anticipate insights from our findings will generate hypotheses that may be tested in future studies in different populations and among victims of different types of elder mistreatment. We also expect that this work will lead to additional uses of claims data to explore the health consequences of elder abuse and to identify utilisation patterns with ‘red flags’ suggestive of exposure. Ultimately, we anticipate that knowledge gleaned will support the future development of a health informatics tool to identify potential victims.

An important limitation of our approach is the use of legally adjudicated cases. Though using this source solves the important methodological challenge of ensuring that case subjects are actually victims of abuse, legally adjudicated cases represent a small percentage of all cases, and abuse victims included may differ in important ways from other victims. They may have experienced more acute or severe abuse allowing identification, and subtle cases of abuse that are more challenging to detect may not have been included. Additionally, other circumstances surrounding the case including the availability of evidence, the willingness of the victim to participate and jurisdiction’s practice pattern may have impacted the decision to prosecute the perpetrator, significantly reducing potential generalisability. An important challenge in previous studies has been accurately classifying subjects as victims of mistreatment. This has likely contributed to inconsistent research findings. Our new potential approach will generate trustworthy results that may identify patterns and generate hypotheses that may be tested. We anticipate that rigorous studies such as ours will lay the necessary groundwork for future studies focused on identifying and examining more subtle cases.

Also, our research strategy relies on linking to Medicare Fee-for-Service records. If subjects were covered by Medicare Advantage or otherwise not covered by Medicare Fee-For-Service for any period, information about their healthcare utilisation would not be available during that period. We have incorporated this potential into our power calculation assumptions, however, and believe we will be able to identify important differences in utilisation.

Another important limitation is that selected control subjects may actually be unidentified cases, reducing the accuracy of our conclusions. Using elder mistreatment diagnoses within Medicare data is not an ideal method for ensuring controls are not cases, given that these diagnoses are infrequently and unreliably included. We hope to overcome this limitation by selecting multiple control cohorts, each with large numbers of controls. Using this approach, and performing sensitivity analyses on our findings, will allow us to identify patterns and draw meaningful conclusions even if a small number of controls are actually abuse victims.

Although we believe that machine learning techniques have enormous potential to find subtle patterns, it is possible that we will not identify any that are clinically identifiable or meaningful. Despite these potential limitations, we believe this research offers a unique opportunity to use a large series of well-characterised cases of physical elder abuse to help us understand the health-related markers that can be used to more validly predict elder abuse and thereby prevent it.

Improved understanding of patterns and associated costs of healthcare utilisation among elder abuse victims, which likely differs substantially from that of other older adults, is potentially very valuable. It may improve the ability of healthcare providers to identify, intervene and prevent victimisation. Furthermore, it may inform policy changes to reduce costs and help this vulnerable population. The research described here represents an important step in exploring the potential of examining healthcare utilisation to provide insight into elder abuse and how to address it.

**ETHICS AND DISSEMINATION**

This project has been reviewed and approved by the Weill Cornell Medicine Institutional Review Board, protocol #1807019417, with initial approval on 1 August 2018. We aim to disseminate our results in peer-reviewed journals at national and international conferences and among interested patient groups and the public.

**Author affiliations**

1Department of Emergency Medicine, Weill Cornell Medicine/NewYork-Presbyterian Hospital, New York, New York, USA
2Department of Health Policy & Research, Weill Cornell Medical College, New York, New York, USA
3Department of Policy Analysis and Management, Cornell University, Ithaca, New York, USA
4Department of Internal Medicine, University of Colorado School of Medicine, Aurora, Colorado, USA
5The Kempe Center for the Prevention & Treatment of Child Abuse & Neglect, University of Colorado School of Medicine, Aurora, Colorado, USA
6John Hopkins University School of Nursing, John Hopkins University, Baltimore, Maryland, USA
7Department of Criminology, University of Delaware, Newark, Delaware, USA
8John A Hartford Foundation, New York, New York, USA
9Division of Geriatrics and Palliative Care, Weill Cornell Medicine/NewYork-Presbyterian Hospital, New York, New York, USA
Acknowledgements We deeply appreciate the continued partnership of our colleagues/partners at the King’s Count District Attorney’s Office in Brooklyn, New York, and the King County Prosecuting Attorney’s Office in Seattle, Washington, without whom this work would not be possible.

Contributors TR, YB, YZ, SC, AE, KP and ML conceived of the study. All authors contributed to the design of the study protocol. TR wrote the manuscript first draft. YB, YZ, SC, KW, AE, PJ, EB, DL, RK, JC, RB, TR, KP and ML contributed to and approved the final manuscript.

Funding This work was supported by a grant from the National Institute on Aging (R01 AG060086). TR’s participation has also been supported by a Paul B. Beeson Emerging Leaders Career Development Award in Aging (K76 AG054866) from the National Institute on Aging. The funder has not been involved in the design or conduct of the research.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; peer reviewed for ethical and funding approval prior to submission.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

ORCID iD
Tony Rosen http://orcid.org/0000-0001-6838-4121

REFERENCES
1. Acero R, Hernandez MA, Amstadter AB, et al. Prevalence and correlates of emotional, physical, sexual, and financial abuse and potential neglect in the United States: the National elder mistreatment study. J Am Public Health 2010;100:292–7.
2. Lachs MS, Pillemer K. Elder abuse. Lancet 2004;364:1263–72.
3. New York City Department for the Aging. Under the radar: new York state elder abuse prevalence study: self-reported prevalence and documented case surveys, 2012. Available: https://ocfs.ny.gov/main/reports/Under%20the%20Radar%202005%202012%20final%20report.pdf [Accessed 10 Feb 2020].
4. National Research Council. Elder mistreatment: abuse, neglect and exploitation in an aging America. Washington, DC: The National Academies Press, 2003.
5. National Center for Elder Abuse. The elder justice roadmap: a Stakeholder initiative to respond to an emerging health, justice, financial, and social crisis. Available: https://www.justice.gov/file/528258/download [Accessed 10 Feb 2020].
6. Lachs MS, Pillemer KA. Elder abuse. N Eng J Med 2015;373:1947–56.
7. Schoffield MJ, Powers JR, Loxton D. Mortality and disability outcomes of self-reported elder abuse: a 12-year prospective investigation. J Am Geriatr Soc 2013;61:679–85.
8. Dyer CB, Pavlik VN, Murphy KP, et al. The high prevalence of depression and dementia in elder abuse or neglect. J Am Geriatr Soc 2000;48:205–8.
9. Lachs MS, Williams CS, O’Brien S, et al. The mortality of elder mistreatment. JAMA 1998;280:428–32.
10. Dong XQ, Simon MA, Beck TT, et al. Elder abuse and mortality: the role of psychological and social wellbeing. Gerontology 2011;57:49–58.
11. Baker MW, LoCroz AI, Wu C, et al. Mortality risk associated with physical and verbal abuse in women aged 50 to 79. J Am Geriatr Soc 2009;57:1799–809.
12. Pillemer K, Finkelhor D. The prevalence of elder abuse: a random sample survey. Gerontologist 1988;28:51–7.
13. Murphy K, Waas S, Jaffee H, et al. A literature review of findings in physical elder abuse. Can Assoc Radiol J 2013;64:10–14.
14. Lachs MS, Williams CS, O’Brien S, et al. Ed use by older victims of family violence. Ann Emerg Med 1997;30:448–54.
15. Bond MC, Butler KH. Elder abuse and neglect: definitions, epidemiology, and approaches to emergency department screening. Clin Geriatr Med 2013;29:257–73.
16. Geroff AJ, Olshaker JS. Elder abuse. Emerg Med Clin North Am 2006;24:491–505.
17. Dong X, Simon MA. Association between elder abuse and use of ED: findings from the Chicago health and aging project. Am J Emerg Med 2013;31:693–8.
18. Friedman LS, Avila S, Tanouye K, et al. A case-control study of severe physical abuse of older adults. J Am Geriatr Soc 2011;59:417–22.
19. Heyborne RD. Elder abuse: keeping the unthinkable in the differential. Acad Emerg Med 2007;14:566–7.
20. Chan KL, Choi WMA, Fong DYT, et al. Characteristics of family violence victims presenting to emergency departments in Hong Kong. J Emerg Med 2013;44:249–58.
21. Dong X, Simon MA. Elder abuse as a risk factor for hospitalization in older persons. JAMA Intern Med 2013;173:91–7.
22. Lachs MS, Williams CS, O’Brien S, et al. Adult protective service use and nursing home placement. Gerontologist 2002;42:734–9.
23. Dong X, Simon MA. Association between reported elder abuse and rates of admission to skilled nursing facilities: findings from a longitudinal population-based cohort study. Gerontology 2013;59:464–72.
24. Mouton CP, Rodabough RJ, Rovi SLD, et al. Prevalence and 3-year incidence of abuse among postmenopausal women. Am J Public Health 2004;94:605–12.
25. Jackson AM, Deye KP, Halley T, et al. Curiosity and critical thinking: identifying child abuse before it is too late. Clin Pediatr 2015;54:54–61.
26. Jenny C, Hymel KP, Ritzer A, et al. Analysis of missing cases of abusive head trauma. JAMA 1999;281:621–6.
27. King WK, Kessler EL, Simon HK. Child abuse fatalities: are we missing opportunities for intervention? Pediatr Emerg Care 2006;22:211–4.
28. Letson MM, Cooper JN, Deans KJ, et al. Prior opportunities to identify abuse in children with abusive head trauma. Child Abuse Negl 2016;60:36–45.
29. Ravichandran D, Schuh S, Beujk M, et al. Delayed identification of pediatric abuse-related fractures. Pediatrics 2010;125:60–6.
30. Thorpe EL, Zuckerbraun NS, Woldorf JE, et al. Missed opportunities to diagnose child physical abuse. Pediatr Emerg Care 2014;30:771–6.
31. Kothari CL, Rhodes K. Missed opportunities: emergency department visits by police-identified victims of intimate partner violence. Ann Emerg Med 2006;47:190–9.
32. Willson P, Cesario S, Frediani N, et al. Primary healthcare provider’s lost opportunity to help abused women. J Am Acad Nurse Pract 2001;13:565–70.
33. Lindberg DM, Beaty B, Juarez-Colunga E, et al. Testing for abuse in children with sentinel injuries. Pediatrics 2015;136:831–8.
34. Sheets LS, Leach ME, Koszewski LJ, et al. Sentinel injuries in infants evaluated for child physical abuse. Pediatrics 2013;131:701–7.
35. Brown DS, Fang X, Florence CS. Medical costs attributable to child maltreatment a systematic review of short- and long-term effects. Am J Prev Med 2011;41:627–35.
36. Rovi S, Chen P-H, Johnson MS. The economic burden of hospitalizations associated with child abuse and neglect. Am J Public Health 2011;101:611–9.
37. Florence C, Brown DS, Fang X, et al. Health care costs associated with child maltreatment: impact on Medicaid. Pediatrics 2013;132:312–8.
38. Jones AS, Diemenn J, Schollnerge J, et al. Long-term costs of intimate partner violence in a sample of female HMO enrollees. Womens Health Issues 2006;16:252–61.
39. Peterson C, Xu L, Florence C, et al. Medical cost of abusive head trauma in the United States. Pediatrics 2014;134:31–9.
40. Miller TR, Steinbeigle R, Lawrence BA. Lifetime cost of abusive child maltreatment: a population-based study of short- and long-term effects. JAMA 2006;295:511–9.
41. Yang J, Miller TR, Zhang N, et al. Incidence and cost of sexual violence in Iowa. Violence Vict 2006;21:139–52.
42. Thielen FW, Ten Have M, de Graaf R, et al. Long-term economic consequences of child maltreatment: a population-focused study. Eur Child Adolesc Psychiatry 2016;25:1297–305.
43. Yang J, Miller TR, Zhang N, et al. Incidence and cost of sexual violence in Iowa. Am J Prev Med 2014;47:199–202.
44. Teresi JA, Burns D, Skowron EA, et al. State of the science on prevention of elder abuse and lessons learned from child abuse and domestic violence prevention: toward a conceptual framework for research. J Elder Abuse Negl 2012;26:263–300.
McCall N. Centers for Medicare and Medicaid services, investigation of increasing rates of hospitalization for ambulatory care sensitive conditions among Medicare fee-for-service beneficiaries. Available: https://www.cms.gov/Research-Statistics-Data-and-Survey-Statistics/Trends-Statistics/Downloads/McCall_2004_3.pdf [Accessed 10 Feb 2020].

Merrick ESL, Hodgkin D, Garnick DW, et al. Older adults' inpatient and emergency department utilization for ambulatory-care-sensitive conditions: relationship with alcohol consumption. J Aging Health 2011;23:86–110.

Brownell J, Wang J, Smith A, et al. Trends in emergency department visits for ambulatory care sensitive conditions by elderly nursing home residents, 2001 to 2010. JAMA Intern Med 2014;174:156–8.

Carter MW, Davis B, Winters JM. Ed visits by older adults for ambulatory care-sensitive and supply-sensitive conditions. Am J Emerg Med 2006;24:428–34.

Duseja R, Bardach NS, Lin GA, et al. Revisit rates and associated costs after an emergency department encounter: a multistate analysis. Ann Intern Med 2015;162:750–6.

Jencks SF, Williams MV, Cooley EA. Rehospitalizations among patients in the Medicare fee-for-service program. N Engl J Med 2009;360:1418–28.

Liu SW, Obermeyer Z, Zhang Y, et al. Frequency of ED revisits and death among older adults after a fall. Am J Emerg Med 2015;33:1012–8.

Vashi AA, Fox JP, Carr BG, et al. Use of hospital-based acute care among patients recently discharged from the hospital. JAMA 2013;309:364–71.

Ahmad M, Lachs MS. Elder abuse and neglect: what physicians can and should do. Cleve Clin J Med 2002;69:801–8.

Rosen T, Stern ME, Elman A, et al. Identifying and initiating intervention for elder abuse and neglect in the emergency department. Clin Geriatr Med 2018;34:435–51.

Friedlaender EY, Alpern E, et al. Patterns of health care use that may identify young children who are at risk for maltreatment. Pediatrics 2005;116:1303–8.

Merrick EL, Hodgkin D, Gar et al. 2001 to 2010. JAMA Intern Med 2015;162:750–6.

LaCalle E, Rabin E. Frequent users of emergency departments: the myths, the data, and the policy implications. Ann Emerg Med 2010;56:42–8.

Locke TE, Baston S, Mason SM, et al. Defining frequent use of an urban emergency department. Emerg Med J 2007;24:398–401.

Davis JW, Fujimoto RY, Chan H, et al. Identifying characteristics of patients with low emergency department visits in a managed care setting. Manag Care 2010;19:38–44.

Uscher-Pines L, Pines J, Kellermann A, et al. Emergency department visits for emergent conditions: a systematic literature review. Am J Manag Care 2013;19:47–59.

Bayliss EA, Ellis JL, Shoup JA, et al. Effect of continuity of care on hospital utilization for seniors with multiple medical conditions in an integrated health care system. Ann Fam Med 2015;13:123–9.

Liss DT, Chubak J, Anderson ML, et al. Patient-reported care coordination: associations with primary care continuity and specialty care use. Ann Fam Med 2011;9:323–9.

Hess LM, Raebel MA, Conner DA, et al. Measurement of adherence in pharmacy administrative databases: a proposal for standard definitions and preferred measures. Ann Pharmacother 2006;40:1280–8.

Carve S, Cleves MA, Helm M, et al. Good and poor adherence: optimal cut-point for adherence measures using administrative claims data. Curr Med Res Opin 2009;25:2303–10.

Colantonio LD, Har Kay K. The relationship between to high-intensity statins following a myocardial infarction hospitalization among Medicare beneficiaries. JAMA Cardiol 2017;2:890–5.

Ostbye T, Taylor DH, Clipp EC, et al. Identification of dementia: agreement among national survey data, Medicare claims, and death certificates. Health Serv Res 2008;43:313–26.

Taylor DH, Fillenbaum GG, Ezell ME. The accuracy of Medicare claims data in identifying Alzheimer’s disease. J Clin Epidemiol 2002;55:929–37.

Faust KR, Jonsson Funk M, Pate V, et al. Using claims data to predict dependency in activities of daily living as a proxy for frailty. Pharmacoeconomics Drug Saf 2015;24:59–66.

Zhang HT, McGrath LJ, Wynn R, et al. Controlling confounding by frailty when estimating influenza vaccine effectiveness using predictors of dependency in activities of daily living. Pharmacoeconomics Drug Saf 2017;26:1500–6.

Rosen T, Bloemen EM, LoFaso VM, et al. Emergency department presentations for injuries in older adults independently known to be victims of elder abuse. J Emerg Med 2016;50:518–26.

Rosen T, LoFaso V, Bloemen EM. Injury patterns in physical elder abuse: preliminary findings from a pilot sample of highly adjudicated cases. San Diego: Society of Academic Emergency Medicine Annual Scientific Meeting, 2015.

Jackson S. Understanding elder abuse: new directions for developing theoretical and conceptual frameworks. Ann Aging Res 2013;11:269–84. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3759781/ [Accessed 10 Feb 2020].
96 Wong NZ, Rosen T, Sanchez AM, et al. Imaging findings in elder abuse: a role for radiologists in detection. Can Assoc Radiol J 2017;68:16–20.
97 Zhang Y, Padman R. Paving the COWPath: learning and visualizing clinical pathways from electronic health record data. Carnegie Mellon University, 2015.
98 Movahedi F, Carey L, Zhang Y. Care pathway after left ventricular assist devices (LVAD) implementation. San Diego, CA: International Society for Heart and Lung Transplantation, 2017.
99 Ghosh S, Li J, Cao L, et al. Septic shock prediction for ICU patients via coupled HMM walking on sequential contrast patterns. J Biomed Inform 2017;66:19–31.
100 Kawamoto R, Nazir A, Kameyama A, et al. Hidden Markov model for analyzing time-series health checkup data. Stud Health Technol Inform 2013;192:491–5.
101 Watkins RE, Eagleson S, Veenendaal B, et al. Disease surveillance using a hidden Markov model. BMC Med Inform Decis Mak 2009;9:39.
102 Zhang Y, Padman R. Innovations in chronic care delivery using data-driven clinical pathways. Am J Manag Care 2015;21:e661–8.
103 Duncan DF, Kum H-C, Weigensberg EC. Informing child welfare policy and practice: using knowledge discovery and data mining technology via a dynamic web site. Child Maltreat 2008;13:383–91.
104 Chung H, Wang W, Duncan D. ApproxMAP: approximate mining of consensus sequential patterns. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.12.2633&rep=rep1&type=pdf [Accessed 10 Feb 2020].
105 Zaki MJ. Spade: an efficient algorithm for mining frequent sequences. Mach Learn 2001;42:31–60.
106 Rabiner L. A tutorial on hidden Markov models and selected applications in speech recognition. IEEE, 1989. Available: http://www.ece.ucsb.edu/Faculty/Rabiner/ee259/Reprints/tutorial%20on%20hmm%20and%20applications.pdf [Accessed 10 Feb 2020].