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Emergency department arrival times in Florida heart failure patients utilizing Fisher-Rao curve registration: A descriptive population-based study

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ABSTRACT

Background: Emergency room utilization and hospital readmission rates are disproportionately high for heart failure patients (HF). Emergency department (ED) utilization is intimately intertwined with hospital readmissions.
Objective: Describe the arrival time distribution of HF patients presenting to the ED.
Method: The study analyzed heart failure discharge data from the Florida State Emergency Department Database and the Florida State Inpatient Database from the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality. Data were treated as a Poisson process and analyzed using functional data analysis tools.
Results: HF arrivals are multi-modal with the largest peak arrival time in the middle of the day as well as a smaller peak in the early morning hours, especially in rural areas.
Conclusions: The arrival pattern has minor differences in rural and urban areas. HF clinic appointments should be established in the early morning hours when these patients utilize the ED.

Background

Heart disease is the leading cause of death in the United States.[1–3] There are 6.5 million Americans currently suffering from heart failure (HF), with close to one million patients being newly diagnosed with HF each year and one in nine death certificates citing HF as a contributing factor. Additionally, the incidence of HF diagnoses is approximately 21 per 1,000 population[1] among adults older than 65. Heart failure-related morbidity is a national health challenge and a priority focus for practice and research initiatives at all levels and areas of care. In particular, the emergency settings where HF patients typically present for initial heart failure symptoms and episodes of disease exacerbation can provide opportunities for early intervention especially among underserved populations. In 2014, there were 459,000 emergency department (ED) and 900,000 hospital discharges with a HF primary diagnosis, and there were almost 2.4 million physician office visits with a HF primary discharge diagnosis.[1] While the number of hospital discharges has remained steady since 2005, it is substantially higher than it was in 1979.[4] According to a recent survey by the American College of Emergency Physicians, 75% of surveyed emergency physicians indicated that the patient volume in their respective EDs has increased since January 2014. Furthermore, 70% of physicians surveyed believe their EDs do not have sufficient resources to handle potentially significant increases in patient volume.[5] The capacity of EDs to staff in such a way as to provide optimal care to HF patients is crucial considering the resource-intensive nature of these highly complex patients.

Insurance is an important factor that affects emergency care, hospital admissions, and readmissions. Since the majority of HF patients are older than 65, Medicare reimbursement rates and rules play a major role in the development of hospital policies which can be further impacted by state and federal legislation. In an attempt to reduce healthcare costs and improve health outcomes, the Patient Protection and Affordable Care Act of 2010 (ACA) was enacted.[6] Under the ACA, the Hospital Readmission Reduction Program (HRRP) was enacted in 2012 with the goal of reducing hospital readmissions of Medicare patients diagnosed with HF, pneumonia, acute myocardial infarction, chronic obstructive pulmonary disease (COPD),

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Table 1
Hospitals in Florida at risk for reduced Medicare reimbursements under HRRP 2011-2014[7]

Diagnosis	% at Risk
Heart Failure	63.5
Pneumonia	53.5
Chronic Obstructive Pulmonary Disease	52.9
Acute myocardial infarction	47.1
Total hip or knee replacement	45.9

or total knee/hip replacements.[7] The potential financial impact on hospitals can be costly since the imposed penalties for higher than expected readmission rates can result in up to a maximum of a three percent reduction in *all* Medicare reimbursements, regardless of diagnosis.

The HRRP had an especially large effect on Florida hospitals between July 2011 and June 2014. For three of the five conditions classified by the HRRP, more than half of the hospitals in the state were at risk for reduced Medicare reimbursements (Table 1). Furthermore, in Florida for 2014, when compared with all other types of insurance, Medicare patients accounted for 17.3% of all ED visits that did not result in an inpatient stay and 25.8% of all ED charges with the highest average cost per visit of $8,350.67. Notably, 78.1% of all HF ED visits were Medicare patients.[8,9] Given the high numbers of HF patients presenting for care, their level of morbidity, and reimbursement risks undertaken by facilities when they re-present for care, it is essential that hospitals equip themselves to address the influx of these patients.

In addition to insurance status, geographic location plays an important role in access to healthcare. In fact, rural patients have typically have lower socioeconomic status,[10] limited access to healthcare,[11,12] and lower levels of health literacy[13] with rural patients who have low or marginal health literacy being more likely to experience readmission or death.[14] Furthermore, heart failure outcomes are worse among rural patients than urban patients.[15] Given the limited access to resources and the severity of outcomes (such as heart-failure related mortality), it is not surprising that rural heart failure patients have higher rates of ED utilization than urban heart failure patients.[16]

While several studies exist in the scientific literature about ED utilization,[17–25] only a few studies have examined the ED arrival times.[26–29] Most studies that analyzed arrival times used methods for binning the 24-hour period into smaller blocks of time and merely counting the arrivals. However, this process results in the loss of the true underlying pattern in the data when considering ED arrival data with temporal variation. There is a crucial need for recognizing ED arrival pattern differences because of their influential effects on ED care-related decisions and perceptions. For example, the time of arrival in the ED has been associated with treatment timeliness and overall patient satisfaction with the care received during hospitalization.[30] Additionally, the time of day and day of the week of patient presentation and triage in the ED predicted disposition[31] and influenced decisions to admit rather than discharge patients.[32] Further analysis of arrival time patterns including consideration of insurance and geography can potentially improve the complex care of HF patients and associated outcomes.

Purpose

The purpose of this descriptive retrospective study was to provide a general description about how HF patients utilize the ED across an entire state. The aim of this study was to describe the mean weekday arrival pattern (the mean weekday arrival pattern is described in methods section) for all HF patients across all EDs in Florida. Additionally, the study provides a descriptive comparison of the mean weekday ED arrival pattern 1) at facilities that treat HF patients with private insurance, Medicare, and Medicaid; 2) at facilities that are located in urban and rural regions; and 3) for first visits and re-visits.

Methods

Design

The study used a descriptive retrospective design to analyze the Florida emergency department arrival pattern for heart failure patients during 2014. Since the unit of measurement for this study is the emergency department, the office of the institutional review board (IRB) at the Florida State University determined that the project did not meet the federal definition of research involving human subjects and, therefore, was exempt from further IRB review or approval.

Description of data

Data sources

The individual level of measurement in this study is the hospital ED. In order to examine the pattern of ED arrivals for HF patients, the arrival times for individual HF patients seen in the ED at each facility were obtained from two data sources, namely 1) the 2014 Florida State Inpatient Database (SID) from the Healthcare Cost and Utilization Project (HCUP) at the Agency for Healthcare Research and Quality (AHRQ)[9]; and 2) the 2014 Florida State Emergency Department Database (SEDD) from the HCUP at the AHRQ.[8] The 2014 Florida SID contains information on *all* inpatient stays at Florida community hospitals in 2014. Inpatient stays which began in the ED are included in the 2014 Florida SID. Only the subset of the 2014 Florida SID where the inpatient stay began in the ED was of relevance in this study. The 2014 Florida SEDD contains information on *all* ED visits that did not result in an admission to the facility that houses the ED. With the aim of having a complete data set that represented all emergency department visits in Florida in 2014, data from the 2014 Florida SEDD was merged with the subset of the 2014 Florida SID which contained only inpatient stays that began in the ED. It is important to note that all Florida community hospitals with an ED are included in the HCUP data.

Setting

The data set for the study was derived from Florida hospitals. Florida is a diverse state with a large rural population, and thus, it was important to describe the emergency department arrival rates in both rural and urban community hospitals. Although a rural or urban designation was not listed in either dataset, the patient zip codes were provided. The patient zip codes were cross-tabulated with the facility identification numbers to determine the most prevalent zip codes serviced by each facility. The county most likely serviced by each facility was identified during this process, and the facilities were then classified according to the Florida State Office of Rural Health's Rural County map.[33] In order to maintain the integrity and anonymity of the data, the only information retained was the rural or urban designation of each facility.

Data analysis plan

ED arrivals at each facility were treated as Poisson processes. Poisson processes assume events occur independently, which may not be reasonable when considering all ED arrivals. However, the assumption that patients with HF experience acute exacerbations of their disease independently of each other is reasonable in the absence of any catastrophic incident.[22] A Poisson process is

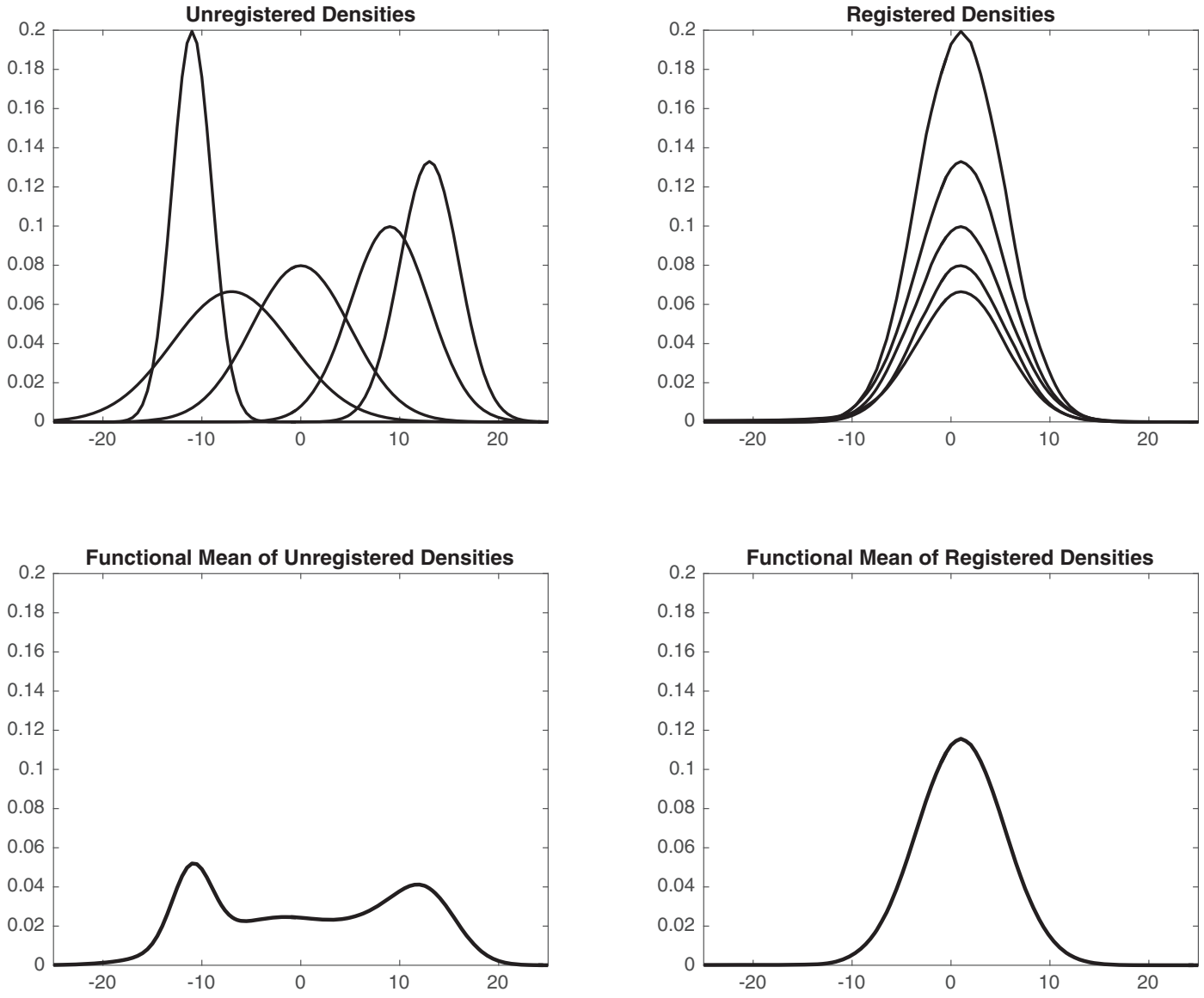

Fig. 1. Illustration of Function Registration – Five curves before (top left) and after (top right) registration along with their functional averages (before: bottom left, after: bottom right).

characterized by its rate function which can be decomposed into two components: 1) a scalar multiplier and 2) the probability density function of the process which contains all information regarding the trend in arrival times and can be estimated using b-spline smoothing methods.[34–36]

The underlying trend in arrival times (also called the mean arrival pattern) contributed by each facility is an example of functional data. Functional data are data generated by some underlying function in a continuous time domain *even if they are only observed at discrete points*. Other examples of functional data in healthcare include electroencephalograms, electrocardiograms, and blood pressure measurements. For more in depth discussions of functional data analysis topics, the reader is referred to Ramsay and Silverman[35] or Srivastava et al.[37]

One task in functional data analysis is to perform function registration as a means for minimizing the effect of variability that exists among functions in the horizontal direction (also called time warping).[37] Figure 1 shows five curves before (top left) and after (top right) implementing the Fisher-Rao method of registration.[37] The cross-sectional mean function, also called the functional average, is the average at each point in time. The functional average is displayed in the bottom row of Figure 1 (left: unregistered, right: registered). Notice how the pattern in the data is lost when computing the functional average without pre-registering the density functions. The functional average of the registered density estimates provides an estimate of the population mean density, a key element in the estimation of the rate function of a Poisson process.

The current paper examines the estimation only of the population mean density function (referred to as the mean arrival pattern). In order to describe the mean arrival pattern in each of our aims (particularly for weekdays), the procedure outlined below was followed:

1. Estimate the individual densities using standard b-spline smoothing methods.
2. Register the densities using the Fisher-Rao metric.
3. Calculate the functional average of the registered density functions for weekday data (mean weekday arrival pattern).

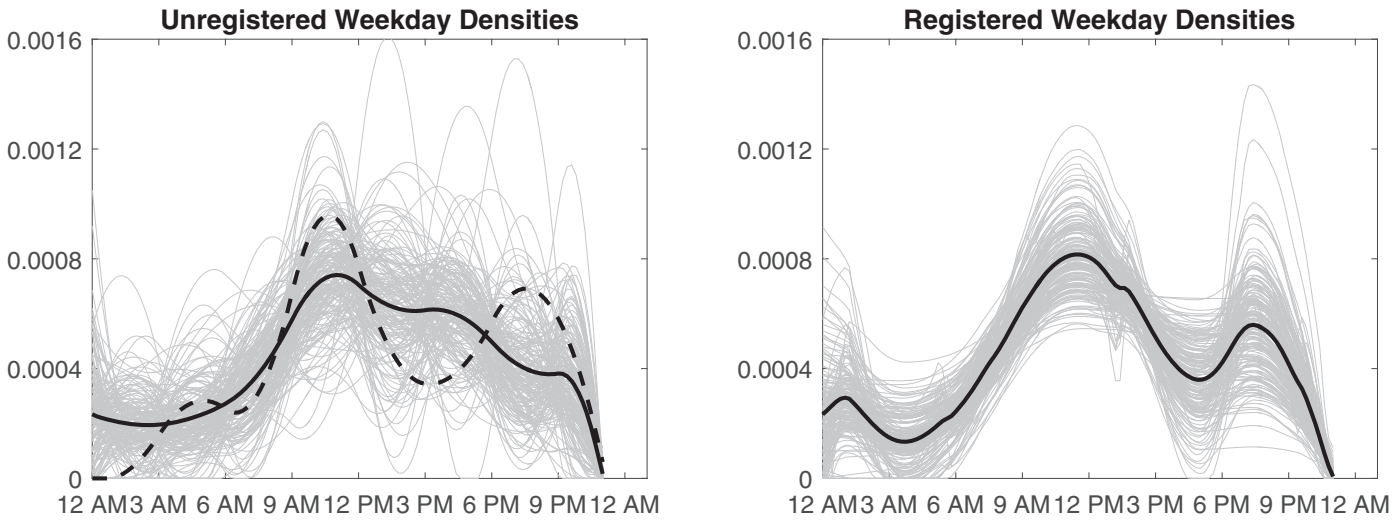

Fig. 2. Gray curves are estimated density curves; the solid black line is the cross-sectional mean of the density curves; the dashed black line is a randomly chosen density to demonstrate pattern in original data. Left – Unregistered weekday density curves; Right – Registered weekday density curves

Results

Weekday HF ED arrival data was gathered on 206 facilities. Of these facilities, 179 were located in urban counties and 27 were situated in rural counties. Only facilities which had enough HF ED arrivals during a weekday to perform the b-spline estimation were considered in the analysis. This resulted in a total of 175 facilities with 14 serving rural counties and 161 serving urban counties.

When the temporal variation across facilities is ignored, the underlying multimodal pattern is lost (Figure 2). However, when accounting for the temporal variation by first registering the functions, the mean becomes more representative of the multimodal structure in the data. When considering insurance status and geographic region type, an apparent interaction is present between the two variables. The mean arrival patterns for insurance status and geographic region are displayed in Figures 3–7.

The results of this study were that all subgroups of patients in the Florida dataset experienced a peak arrival during mid-day with a less pronounced peak in the late afternoon, which is importantly consistent with the results of other studies that analyzed data collected from only one facility.[17,26,27] Additionally, the findings of this study indicated that Medicare patients and patients living in rural areas had a smaller, although prominent, peak arrival time in the early morning hours around 4 AM – 6 AM. Further examination of the data revealed a potential interaction between insurance status and the type of geographic region in which the facility is located. In fact, in urban facilities, Medicare patients' arrival time distribution did not have an early morning peak comparable to the distribution for Medicare patients in rural facilities. Similarly, patients with Medicaid and private insurance also had an early morning peak in the arrival time distribution in rural facilities.

Re-visit analyses

The percentage of HF patient ED visits classified as "re-visits" during 2014 is substantially high (57.7%) compared with the percentage of revisits (46.4%) attributed to all other diagnoses during the same year. As a consequence, the arrival patterns for first time 2014 ED visits related to heart failure and for re-visits associated

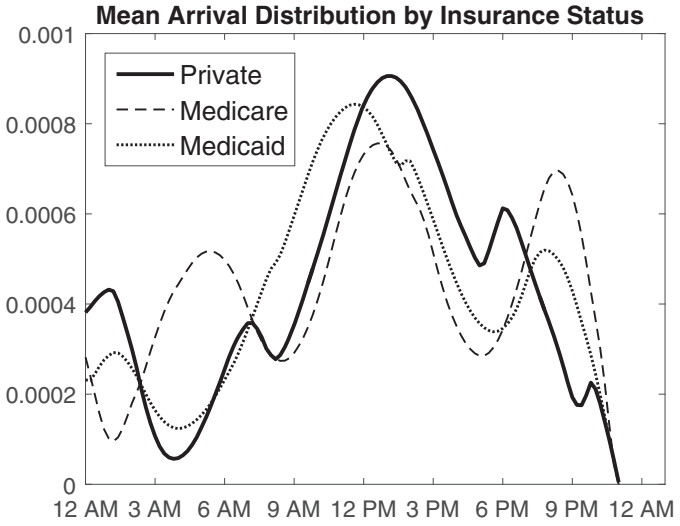

Fig. 3. Mean arrival time distribution by type of insurance

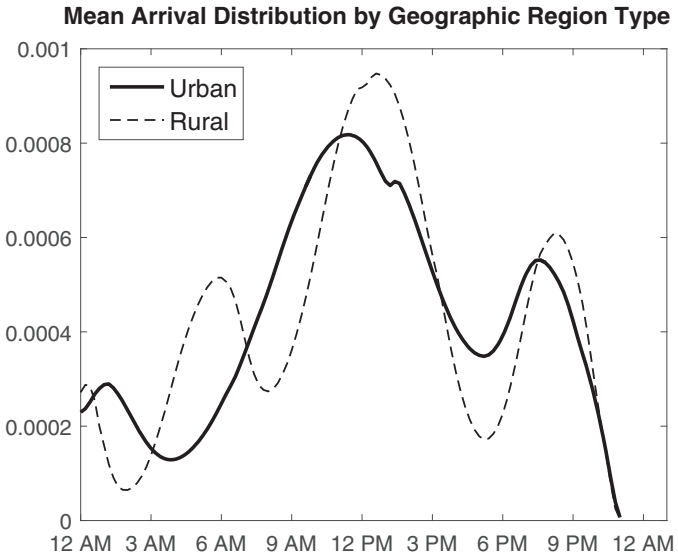

Fig. 4. Mean arrival time distribution by type of geographic region

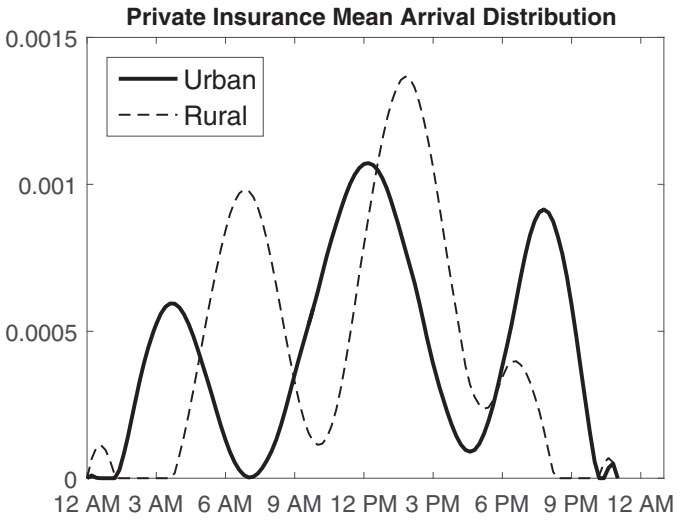

Fig. 5. Mean arrival time distribution of arrivals of privately insured heart failure patients in urban and rural areas

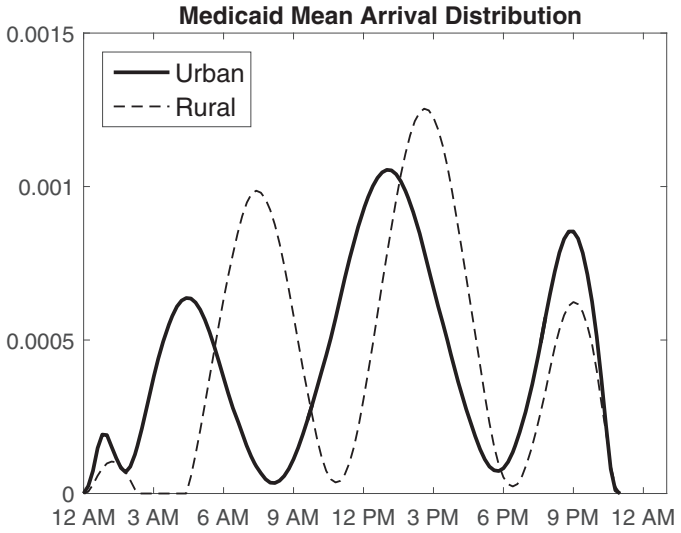

Fig. 7. Mean arrival time distribution of arrivals of Medicaid heart failure patients in urban and rural areas

with HF during that same year were compared. No apparent differences in arrival time pattern were observed between the two groups (Figure 8).

Discussion

Although EDs are overcrowded and individual facilities have studied ED utilization at the facility level, few, if any, studies have examined the distribution of ED arrival times across many facilities at the population level. This study utilized existing functional data analysis tools to examine complex arrival time data for HF patients across many facilities in the state of Florida for 2014. B-spline smoothing and function registration methods allowed for accurate computation of the mean arrival density function for different subgroups of HF patients. This innovative analysis method utilizes the underlying functional structure of the data and provides a more accurate understanding of the mean arrival pattern for HF patient presentation to the ED.

The results of this study supported the findings of other studies regarding the increased patient arrival rates in the mid-day time frame. However, the findings of this study showed an additional peak in arrival times during the early morning hours among EDs located in rural settings which may have important implications for ED staffing patterns and research. The increased influx of complex HF patients accessing care in the early morning hours can potentially challenge rural emergency systems when attempting to meet this demand using limited available healthcare resources including ED staff experienced in caring for people with HF. Research is needed to determine whether the noted difference in early morning arrival patterns among rural populations is a result of a) seeking care in the early morning when symptoms may have initially presented after awakening, or b) seeking care late after presentation and worsening of symptoms throughout the night. Since early intervention for HF presentation can potentially reduce HF morbidity and mortality, the results of this inquiry could be important for advancing health equity and improving HF outcomes among underserved populations.

Despite the knowledge gaps regarding ED utilization, very few studies examined ED utilization in terms of arrival times. Most

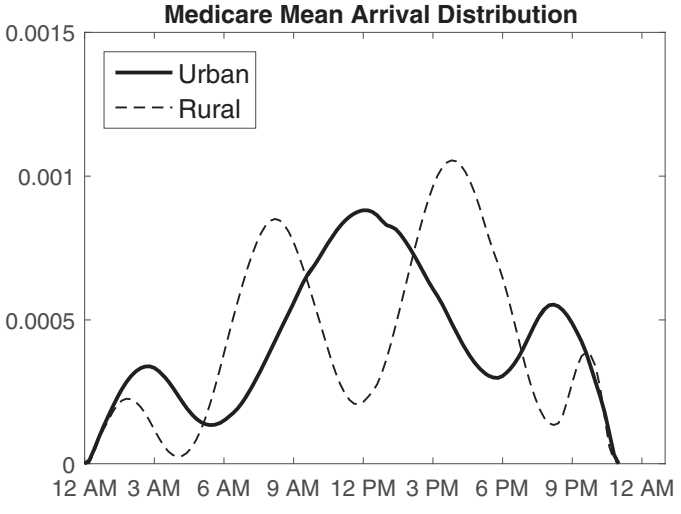

Fig. 6. Mean arrival time distribution of arrivals of Medicare heart failure patients in urban and rural areas

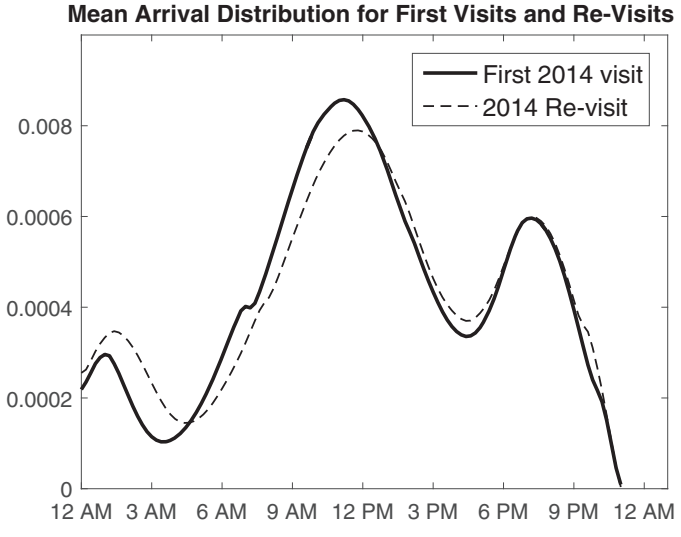

Fig. 8. Mean arrival time distribution for first 2014 visit and 2014 re-visits for heart failure patients

studies of ED utilization are designed to forecast daily, weekly, or monthly utilization[17,18] or to test for associations between utilization and various risk factors for utilization.[19–23] Furthermore, many ED utilization studies in cardiac patients examined the time from ED arrival to the time of life-saving procedures or associations between risk factors and health outcomes without the analysis of the distribution of arrival times.[25] The few studies that examined ED utilization solely as a function of arrival times generally use data from one facility in order to guide resource allocation at that one facility and are not specific to HF. Most of these studies bin the 24-hour time period into 2, 4, or 6-hour intervals and describe the number of arrivals in each interval.[26–28] Yet another study implemented Poisson regression to predict hourly ED arrivals.[29] However, no studies were found that examined the distribution of ED arrival times among many hospitals within a state which could potentially guide state-level initiatives.

While the analysis methods implemented in the aforementioned studies work well within the specific circumstances of each individual study, the results of these studies cannot be generalized to an entire state or region. Describing the average arrival pattern across many emergency departments by binning the day into small periods of time may not provide an accurate representation of the underlying pattern. The rationale is that peak arrivals may occur at different times across facilities, but the underlying trend may have a similar pattern across facilities that would not be captured through data binning. This study bridges this gap by using more advanced statistical methods to analyze ED arrival time data from multiple facilities.

Clinical implications

The findings of the study have important implications for various health professionals practicing in acute care settings where resources are typically limited. Concurrently, federal changes can potentially cause hospitals to lose vitally needed revenue if they fall short of care-related benchmarks, especially considering HF patients.

Access to health care in rural areas is limited,[38–40] and the association between access to care and increased ED utilization is notable.[19,41–43] Furthermore, rural facilities often lack critical resources and may need additional support for planning and resource allocation. For example, the findings of this study suggest that patients and facilities in rural locations may benefit from implementing an early morning heart failure clinic that would offer patients an alternative to emergency department care. However, the data indicated that the density of visits in rural areas, although predictable, would not likely yield significant cost savings or improvements in quality of care when considering patient density in these remote locations.

In contrast, there is a marked difference in the density of patients presenting for care in urban facilities which indicates a potential to positively affect the care of large numbers of patients over a relatively short period of time. Furthermore, these patients represent a significant source of emergency department recidivism, and hospital admission, which can negatively affect a hospital's ability to gain reimbursement from federal programs such as Medicare. An acute care clinic separate from the emergency department could capture the highest density times for patient presentation during the time span of 8 AM through 4 PM. Studies indicate that heart failure clinics that are nurse led[44] and multidisciplinary[45,46] can be effective strategies for treating heart failure patients while reducing revisit and readmission rates. Another strategy that may reduce the need for an ED visit is the use of telemedicine to assess patients and provide timely intervention, when necessary.

Limitations

Despite the statistical rigor of the methods, this study has some limitations. First, the data set utilized covers one year in one state. While the results are applicable to Florida, they may not be generalizable to other states. Second, while it may be reasonable to assume that ED visits across patients are independent, it may not be reasonable to assume that ED visits within each HF patient are independent. Third, the cross-sectional design of the study does not allow for the examination of repeated ED visits for patients with HF. Lastly, this study is descriptive, and the results should be taken only as a preliminary step towards future research.

Additionally, there are some limitations inherent in all secondary analyses due to methodologies in data collection or availability of data elements in existing data sources. In particular, availability of data elements can pose problems in secondary analyses when authors are forced to make assumptions regarding existing data. For example, the dataset used for this study did not provide the exact time of arrival. The hour of arrival is provided, and uniform noise is added to obtain a unique arrival time. However, this should not have a large impact on the overall arrival pattern but may introduce some additional variability into the estimates. Another limitation in the dataset was that the exact day of arrival was not provided, and variations throughout the week could not be accounted for beyond weekday and weekend comparisons. Finally, it is known that there are seasonal variations in daily ED utilization.[19] While the daily count of ED arrivals varies seasonally, the assumptions for this study were that the daily underlying trend of arrivals remained the same across seasons, which may not be reasonable.

Future research directions

While the limitations of this study may limit generalizability, the findings of this study can be used to provide a starting point for examining ED arrival times as functional data. The results, and the limitations, can fuel additional research grounded in the theory of functional data analysis. For example, future research should consider modeling ED arrival times with counting processes that can account for the dependence among visits within each patient. Additionally, future research should consider utilizing data from other states to provide a larger geographic context and improve the generalizability of the results. Furthermore, functional regression models which model the mean arrival pattern as a function of covariates and potential confounders should be considered. These variables may include regional characteristics, specific hospital characteristics including, the type of geographic region served by the facility, proportion of underserved patients seen at the facility, the size of the facility, and the availability of a heart failure clinic at the facility as well as socio-demographic information about the population such as median household income, unemployment rate, and educational attainment levels. While this study provides preliminary evidence that suggests the mean ED arrival pattern for HF patients differs in rural and urban areas and across the various insurance statuses, additional analyses should consider testing these hypotheses.

Conclusion

To provide timely access to care for HF patients, it is essential that researchers identify trends in the arrival times of HF patients at health care facilities that could facilitate the ability of hospital staff to estimate patterns of presentation. The findings of this study extend the current body of literature by utilizing functional data analysis methods to describe the underlying trend in the ED arrival time distribution for different subgroups of HF patients across the

entire state of Florida. Additionally, findings from this study can be used to inform recommendations such as offering flexible HF clinic hours to patients in rural areas. Further examination of the impact of seasonal variations on the hourly arrival time distribution should be considered in future research.

References

1. Benjamin EJ, Virani SS, Callaway CW, et al. Heart disease and stroke statistics – 2018 update: a report from the American Heart Association. *Circulation*. 2018;137:e1–e441. doi:10.1161/CIR0000000000000558.
2. Heidenreich PA, Trogdon JG, Khavjou OA, et al. Forecasting the future of cardiovascular disease in the United States: a policy statement from the American Heart Association. *Circulation*. 2011;123:933–944. doi:10.1161/HHF.0b013e318291329a.
3. National Center on Health Statistics. Health, United States, 2015: With special feature on racial and ethnic health disparities. Hyattsville, Maryland: National Center for Health Statistics (US); 2016.
4. Rosamond W, Flegal K, Furie K, et al. Heart disease and stroke statistics – 2008 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. *Circulation*. 2008;117:e25–e146. doi:10.1161/CIRCULATIONAHA.107.187998.
5. Marketing General Incorporated. American College of Emergency Physicians Poll Affordable Care Act research results. Alexandria, VA: 2015.
6. The Henry J. Kaiser Family Foundation. Summary of the Affordable Care Act. Kaiser Family Foundation Website. http://kff.org/health-reform/fact-sheet/summary-of-the-affordable-care-act/. Accessed August 27, 2016.
7. Centers for Medicare and Medicaid Services. Hospital Readmission Reduction Program Website. https://www.cms.gov/medicare/medicare-fee-for-service-payment/acuteinpatientpps/readmissions-reduction-program.html. Accessed August 1, 2016.
8. HCUP State Emergency Department Databases (SEDD). Healthcare Cost and Utilization Project (HCUP). Rockville, MD.: Agency for Healthcare Research and Quality; 2014. www.hcup-us.ahrq.gov/seddoverview.jsp.
9. HCUP State Inpatient Databases (SID). Healthcare Cost and Utilization Project (HCUP). Rockville, MD.: Agency for Healthcare Research and Quality; 2014. www.hcup-us.ahrq.gov/sidoverview.jsp.
10. Fisher M. Why is U.S. poverty higher in nonmetropolitan than in metropolitan areas? *Growth Change*. 2007;38:56–76.
11. Chan L, Hart LG, Goodman DC. Geographic access to health care for rural Medicare beneficiaries. *J Rural Health*. 2006;22:140–146.
12. Dracup K, Moser DK, Pelter MM, et al. Randomized, controlled trial to improve self-care in patients with heart failure living in rural areas. *Circulation*. 2014;130:256–264. https://doi.org/10.1161/CIRCULATIONAHA.113.003542.
13. Zahnd WE, Scaife SL, Francis ML. Health literacy skills in rural and urban populations. *Am J Health Behav*. 2009;33:550–557.
14. Moser DK, Robinson S, Biddle MJ, et al. Health literacy predicts morbidity and mortality in rural patients with heart failure. *J Cardiac Fail*. 2015;21:612–618.
15. Brar S, McAlister FA, Youngson E, Rowe BH. Do out comes for heart failure patients vary by emergency department volume? *Circ Heart Fail*. 2013;6:1147–1154.
16. Gamble J-M, Eurich DT, Ezekowitz JA, Kaul P, Quan H, McAlister FA. Patterns of care and outcomes differ for urban versus rural patients with newly diagnoses heart failure, even in a universal healthcare system. *Circ Heart Fail*. 2011;4:317–323.
17. Cote MJ, Smith MA, Eitel DR Akcail E. Forecasting emergency department arrivals: a tutorial for emergency department directors. *Hosp Top*. 2013;91:9–19. doi:10.1080/00185868.2013.757962.
18. Au-Yeung SWM, Harder U, McCoy EJ, Knottenbelt WJ. Predicting patient arrivals to an accident and emergency department. *Emerg Med J*. 2009;26:241–244.
19. Bazargan M, Bazargan S, Baker RS. Emergency department utilization, hospital admissions, and physicians visits among elderly african american persons. *Gerontologist*. 1998;38:25–36. doi:10.1136/emj.2007.051656.
20. Guevara JP, Mandell D, Danagoulian S, Reyner J, Pati S. Parental depressive symptoms and children's school attendance and emergency department use: a nationally representative study. *Matern Child Health J*. 2013;17:1130–1137. doi:10.1007/s10995-012-1109-5.
21. Kerr J, Duffus WA, Stephens T. Relationship of HIV care engagement to emergency department utilization. *AIDS Care*. 2014;26:547–553. doi:10.1080/09540121.2013.844764.
22. Baker LC, Hsia RY. The association between community-level insurance coverage and emergency department use. *Med Care*. 2014;52:535–540. doi:10.1097/MLR.0000000000000136.
23. Levy M, Broccoli M, Cole G, Jenkins JL, Klein EY. An analysis of the relationship between the heat index and arrivals in the emergency department. *PLoS Curr*. 2015;7:doi:10.1371/currents.dis.64546103ed4fa0bc7c5b779dd16f5358. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4635022/. Accessed January 27, 2016. ecurrents.currents.dis.64546103ed4fa0bc7c5b779dd16f5358.
24. Bagai A, Jollis JG, Dauerman HL, et al. Emergency department bypass for ST-Segment Elevation Myocardial Infarction patients identified with a pre-hospital electrocardiogram: a report from the American Heart Association Mission: Lifeline™ Program. *Circulation*. 2013;128:352–359. doi:10.1161/CIRCULATIONAHA.113.002339.
25. Menees DS, Peterson ED, Wang Y, et al. Door-to-balloon time and mortality among patients undergoing primary PCI. *N Engl J Med*. 2013;369:901–909. doi:10.1056/NEJMoa1208200.
26. Seow E, Wong HP, Phe A. The pattern of ambulance arrivals in the emergency department of an acute care hospital in Singapore. *Emerg Med J*. 2001;18:297–299. PMID: 11435372.
27. Tiwari Y, Goel S, Singh A. Arrival time pattern and waiting time distribution of patients in the emergency outpatient department of a tertiary level health care institution of North India. *J Emerg Trauma Shock*. 2014;7:160–165. doi:10.4103/0974–2700.136855.
28. Conlon C, O'Connor C, McBrearty P, Carpenter B. Minor injury attendance times to the ED. *Int Emerg Nurs*. 2009;17:169–172. doi:10.1016/j.ienj.2008.12.006.
29. McCarthy ML, Zeger SL, Ding R, Aronsky D, Hoot NR, Kelen GD. The challenge of predicting demand for emergency department services. *Acad Emerg Med*. 2008;15:337–346. doi:10.1111/j.1553-2712.2008.00083.x.
30. Burgemeister S, Kutz A, Conca A, et al. Comparative quality measures of emergency care: An outcome cockpit proposal to survey clinical processes in real life. *Open Access Emerg Med*. 2017;9:97–106. doi:10.2147/OAEM.S145342. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5661482/.
31. Kim SW, Li JY, Hakendorf PL, Teubner DJ, Ben-Tovim D, Thompson CH. Predicting admission of patients by their presentation to the emergency department. *Emerg Med Aust*. 2014;26:361–367. https://onlinelibrary.wiley.com/doi/pdf/10.1111/1742-6723.12252.
32. Pope I, Burn H, Ismail SA, Harris T, McCoy D. A qualitative study exploring the factors influencing admission to hospital from the emergency department. *BMJ Open*. 2017;7:e011543. doi:10.1136/bmjopen-2016-011543. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5577896/.
33. Florida State Office of Rural Health. Florida Rural Counties Map. http://www.floridahealth.gov/provider-and-partner-resources/community-health-workers/health-professional-shortage-designations/Rural%20Counties%20Map%202016.pdf. Accessed August 22, 2016.
34. de Boor C. B(asic)-spline basics. In: Piegl L, ed. *Fundamental Developments of Computer Aided Geometric Modeling*. London, England.: Academic Press; 1993.
35. Ramsay JO, Silverman BW. Functional Data Analysis. 2nd ed. New York, NY: Springer Series in Statistics; 2005.
36. Ramsay J, Hooker G, Graves S. Functional Data Analysis with R and Matlab. New York, NY: Springer Series in Statistics; 2009.
37. Srivastava A, Wu W, Kurtek S, Klassen E, Marron JS. Registration of functional data using Fisher-Rao metric. ArXiv:1103.3817v2 [math.ST]; 2011. https://arxiv.org/pdf/1103.3817.pdf. Accessed December 10, 2013.
38. Skinner AC, Slifkin RT. Rural/urban differences in barriers to and burden of care for children with special health care needs. *J Rural Health*. 2007;23:150–157. doi:10.1111/j.1748-0361.2007.00082.x.
39. Rhodes KV, Bisgaier J, Lawson CC, Soglin D, Krug S, Van Haitsma M. Patients who can't get an appointment go to the ER": access to specialty care for publicly insured children. *Ann Emerg Med*. 2013;61:394–403. doi:10.1016/j.annemergmed.2012.10.030.
40. Baskin LW, Baker JR, Bryan TL, Young GQ, Powell-Young YM. Rural Health and the nonemergency use of emergency medical services. *Nurs Clin N Am*. 2015;50:613–619. doi:10.1016/j.cnur.2015.05.014. PMID: 26333615.
41. Cheung PT, Wiler JL, Lowe RA, Ginde AA. National study of barriers to timely primary care and emergency department utilization among Medicaid beneficiaries. *Ann Emerg Med*. 2012;60:4–10. doi:10.1016/j.annemergmed.2012.01.035.
42. Carter-Templeton HD, Wu L. The nursing clinics of North America: Using mobile technologies to access evidence-based resources: a rural health clinic experience. *Nurs Clin N Am*. 2015;50:595–603. doi:10.1016/j.cnur.2015.05.012.
43. Zhu X, Mueller KJ, Vaughn T, Ullrich F. A rural taxonomy of population and health-resource characteristics. Rural Policy Research Institute Center for Rural Health Policy Analysis Rural Policy Brief No. 2015-4; 2015. http://cph.uiowa.edu/rupri/publications/policybriefs/2015/Rural%20Taxonomy%20Brief.pdf. Accessed August 20, 2016.
44. Cheng H, Chair S, Wang Q, Sit J, Wong E, Tang S. Effects of a nurse-led heart failure clinic on hospital readmission and mortality in Hong Kong. *J Geriatric Cardiol*. 2016;13:415–419.
45. Wijeysundera H, Trubiani G, Wang X, et al. A population-based study to evaluate the effectiveness of multidisciplinary heart failure clinics and identify important service components. *Circ Heart Fail*. 2013;6:68–75.
46. Jackevisius C, de Leon N, Chang D, Warner A, Mody F. Impact of a multidisciplinary heart failure post hospitalization program on heart failure readmission rates. *Ann Pharmacother*. 2015;49:1189–1196.