Published in final edited form as:

Clin Pulm Med. 2018 May ; 25(3): 79–83. doi:10.1097/CPM.0000000000000254.

Readmissions Among Sepsis Survivors: Risk Factors and Prevention

Andrew J. Goodwin, MD, MSCR¹ and Dee W. Ford, MD, MSCR¹

¹Division of Pulmonary, Critical Care, Allergy and Sleep Medicine, Medical University of South Carolina

Abstract

Hospital readmissions are common and result in increased mortality and cost while reducing quality of life. Readmission rates have been subjected to increasing scrutiny in recent years as part of a larger effort to improve the quality and value of healthcare in the United States. Emerging evidence suggests that sepsis survivors are at high risk for hospital readmission and experience readmission rates comparable to survivors of congestive heart failure, acute myocardial infarction, pneumonia, and chronic obstructive pulmonary disease, diseases whose readmission rates determine reimbursement penalties from the federal government. In this article, we review the unique challenges that sepsis survivors face as well as the patient-level and hospital-level risk factors that are known to be associated with hospital readmission after sepsis survival.

Additionally, we identify the causes and outcomes of readmissions in this population before concluding with a discussion of readmission prevention strategies and future directions.

Keywords

Sepsis; Readmission; Prevention; Comorbidities

Introduction

Sepsis is a major public health threat. With over 19 million cases each year worldwide, sepsis accounts for 10% of all intensive care unit (ICU) admissions. (1) It is associated with high morbidity and mortality rates and in the United States (US) alone, its care is estimated to cost over \$20 billion. (2, 3) Several recent studies have demonstrated that sepsis incidence is rising, while concurrently, implementation of evidence-based sepsis care processes have resulted in a reduction of in-hospital sepsis mortality. (2, 4, 5) These intersecting phenomena are working in concert to create a growing population of sepsis survivors afflicted with cognitive, physical, and psychological sequelae and a disproportionate risk for hospital readmission (6–8). Index admissions for sepsis result in the second highest readmission rate among Medicare beneficiaries, second only to admissions for congestive heart failure

Corresponding Author: Andrew J. Goodwin, MD, MSCR, Division of Pulmonary, Critical Care, Allergy and Sleep Medicine, Clinical Sciences Building 816, MSC 630, 96 Jonathan Lucas St., Charleston, SC 29466, goodwian@muscc.edu, Ph: 843-792-4728, F: 843-876-2057.

The authors report no conflicts of interest.

(CHF). (9) Here, we provide a review of the emerging problem of hospital readmissions among sepsis survivors with focus on the current literature surrounding hospital readmissions, the unique challenges among sepsis survivors that predispose them to readmission, and potential preventative strategies for this at-risk population.

Hospital Readmissions

Frequency and Societal Impact

Hospital readmissions have garnered increasing recent attention as they are common and have far-reaching implications for patients and society. (10) There are approximately 3.3 million annual readmissions in the US with as many as 1 in 5 Medicare beneficiaries needing readmission within 30 days of discharge and 1 in 3 within 90 days. (9, 11) In addition to substantial mortality, readmissions reduce patient quality of life and cost an estimated \$41 billion per year. (9, 12) As 30 day readmissions have been associated with substandard hospital care and post-discharge processes (13–15), it is widely believed that a proportion of these readmissions are avoidable. (16) This assertion and the increasing societal burden imposed by hospital readmissions served as the impetus for the creation of the US government's Hospital Readmission Reduction Program (HRRP).

Hospital Readmission Reduction Program

As one of the pay-for-performance initiatives of the Patient Protection and Affordable Care Act, the HRRP was established in 2012. The program compares the observed and expected readmission rates of key diagnoses for each hospital and financially penalizes hospitals with higher than expected readmission rates. The initial iteration of the program targeted readmission rates after admission for CHF, acute myocardial infarction (AMI) and pneumonia as these diagnoses are known to be complicated by frequent readmissions. (11, 17) Over time, the HRRP has evolved to include penalties for excessive readmissions after index admissions for chronic obstructive pulmonary disease (COPD), hip or knee arthroplasty, and, most recently, coronary artery bypass grafting (CABG). Further, the maximum penalties associated with excessive readmissions have grown from 1% of all annual Centers for Medicare and Medicaid Services (CMS) reimbursements to 3%. (18)

Since its inception, the HRRP has resulted in substantial financial penalties for US hospitals including \$528 million in fiscal year 2017, the highest such penalty to date. Teaching hospitals and those that provide care to higher proportions of low-income Medicare patients, have incurred the highest penalties. (19) In response, hospitals are developing new strategies to reduce 30-day readmissions which have begun to curb hospital readmissions after heart failure, heart attack and pneumonia admissions. Although the proportion of hospitals that are penalized by the HRRP has increased from 64% to 79% from 2013 to the present, this appears to be due to the sequential addition of new diagnoses to the program rather than increasing readmission rates. (19)

Controversies of Hospital Readmission Reduction

To no surprise, the HRRP has sparked controversy and debate since its introduction. (20) A fundamental concern has centered on the precision and validity of the algorithms used by

CMS to determine the “expected” readmission rate for a particular condition. Estimates of preventable readmissions vary considerably as have reductions in readmission rates in response to targeted interventions. (21) Such variability poses a significant challenge for the accurate modeling of readmission risk as evidenced by these models’ modest ability to account for readmission variance. (22) Further, despite evidence that readmission rates are directly associated with the proportion of socioeconomically disadvantaged patients a hospital treats, CMS has elected not to control for socioeconomic status (SES) until only recently. (19)

Associations between inpatient mortality and length of stay (LOS) and readmission rates have also generated concern that hospitals with low inpatient mortality rates and lengths of stay may be disproportionately penalized for excessive readmission rates. Analysis of the CMS hospital compare data demonstrated an inverse relationship between risk-adjusted hospital mortality and risk-adjusted readmission rates among patients admitted with CHF. (23) The authors suggest that this relationship may be due to an enlarged pool of at-risk survivors in hospitals with low in-hospital mortality rates. However, recent, rigorous analyses have reassuringly suggested that readmission rates are minimally, if at all, associated with in-hospital mortality (24) and that hospitals which improved their readmission rates over time also improved their post-discharge mortality rates. (25) Similarly, several studies have identified inverse relationships between index admission LOS and readmission rates. (26–28) However, temporal analysis of Veterans Affairs (VA) outcomes data has shown that as LOS for all medical diagnoses has decreased over time, so too have readmission rates, arguing against an obligate increase in readmissions as LOS is reduced. (29)

Readmissions Among Sepsis Survivors

Complications of Sepsis Survival

Critical illness survivors experience high rates of morbidity that can persist after discharge resulting in increased vulnerability to hospital readmission. For example, admission with severe sepsis is associated with the development of new cognitive impairment and functional disability in survivors, sequelae that can persist for years. (6) Similarly, survivors of sepsis-related ARDS commonly experience long-term limitations in physical function. (7) And, approximately one-third of critical illness survivors experience depressive symptoms, (8) which have been associated with hospital readmission in both medical and post-surgical populations. (30, 31) This constellation of cognitive, physical and psychiatric complications in critical illness survivors has been coined the Post-ICU Syndrome, an increasingly recognized phenomenon leading to post-discharge fragility and vulnerability. Not surprisingly, survivors of sepsis utilize healthcare at high rates that are out of proportion to those of survivors of non-sepsis hospitalizations (32) and a significant proportion of this utilization comes in the form of 30 day hospital readmissions.

Rates and Risk Factors for Readmission

Recently, several studies have examined the rates of 30 day hospital readmission among sepsis survivors. Their findings have been remarkably consistent with readmission rates

ranging from 18–26% across clinical settings ranging from community hospitals to large, academic tertiary care centers. (12, 33–37) These rates are comparable to those of CHF, AMI, pneumonia and COPD (11, 38). In fact, among Medicare beneficiaries, sepsis is second only to CHF among conditions which lead to 30 day readmissions. Further, if the readmission rates among survivors of pneumonia (a common cause of sepsis which is commonly tracked independently) are combined with sepsis, it would be the most common condition leading to readmissions among this population. (9) This observation has subsequently been validated in a large, national cohort of all beneficiary types where sepsis was found to be a leading diagnosis resulting in readmission and responsible for 7–12% of all readmissions nationwide. (39)

Several recent studies have sought to identify risk factors for readmission after sepsis hospitalization in order to help identify the subset of survivors who are at the greatest risk (Table 1). A number of patient demographics have been associated with readmission among sepsis survivors including black and native American race, lower income, and Medicare or Medicaid beneficiary status. The common denominator of each of these risk factors may be limited access to healthcare which can impact readmission rates both through poor comorbidity management and/or inadequate follow up after discharge. The impact of gender on readmission risk is unclear; it has been shown to have weak associations with readmission with one study suggesting that females have higher odds of readmission while another study demonstrated that females have lower odds of readmission. Age appears to have a complex relationship with 30 day readmissions as younger age is associated with lower odds of readmission as is age over 80. This latter finding may be the result of palliative decisions to not readmit the very elderly if they are able to survive their index admission for sepsis.

Patient co-morbidities are among the most consistently identified risk factors for hospital readmission among sepsis survivors. In fact, comorbid illness may be a more important risk factor for 30 day readmissions than the severity of illness during the index hospitalization. (12) Both individual comorbidities and increasing aggregate comorbidity burden is associated with a higher risk of 30 day readmissions. (33, 34) Specifically, the presence of malignancy, collagen vascular disease, chronic kidney, liver, or lung disease, CHF, or diabetes mellitus are all associated with increased odds of sepsis survivor readmission. (12, 36) Hospitalization for any cause within the preceding year is also associated with readmissions and may be a marker of increased comorbidity burden. (36, 37)

In addition to pre-existing patient factors, characteristics of the index hospitalization for sepsis have also been linked to readmissions. The need for intensive care or procedures, longer length of stay, total parental nutrition use, anemia and discharge to a healthcare facility have all been associated with higher rates of readmission. (12, 33, 34, 36, 37, 40). Further, the characteristics of the hospital where the index sepsis admission took place also influence the risk of readmission. University hospitals and hospitals which care for a high proportion of minority patients experience the highest rates of readmission among survivors of sepsis while for-profit status and higher annual sepsis case volumes are also known risk factors. (12, 34, 35)

Causes and Outcomes of Readmissions

Over half of 30 day readmissions among sepsis survivors come in the first 15 days after discharge and approximately one-third occur within the first 7 days. (36) The most common cause of 30 day readmissions among sepsis survivors is infection and/or sepsis although most datasets have lacked sufficient granularity to determine whether these are readmissions for unresolved or new infections. (12, 33, 35, 37) Additional causes of readmission include respiratory failure, complications related to care during the index hospitalization, and CHF although these are all much less common among most survivors than readmission for infection. (35) Of note, CHF was found to be the most frequent cause of readmission in a veterans affairs hospitals cohort of sepsis survivors. However, among veterans who were discharged to a nursing facility after their index admission, infections were the leading cause of readmission suggesting that discharge destination is associated with distinct risks for readmission. (41)

Thirty day readmissions lead to significant mortality among sepsis survivors and contribute substantial cost to the healthcare system. Mortality rates during 30 day readmissions after sepsis survival range from 6.5–14.4% (12, 35–37) and are significantly higher than mortality rates during readmission after other conditions such as CHF or AMI. (36) On average, these readmissions cost \$25,000–\$30,000 each and are estimated to cost \$1.4B annually for Medicare beneficiaries alone. (9, 12, 35)

Preventing Readmissions After Sepsis Survival

The association between sepsis survival and readmission risk is a relatively new observation; thus, there have been no published studies focused on reducing readmissions among sepsis survivors to date. However, in the context of high sepsis readmission rates, an increasing level of scrutiny on sepsis care processes or ‘bundles’ by CMS, (42) and a heightened focus on readmission reduction by hospital administrators, (43) it is likely that future investigation will be forthcoming. A variety of peri-discharge processes and interventions have been examined in survivors of other diseases with varying results (Table 2). Post-discharge medication reconciliation and symptom tracking are cost-effective strategies for readmission prevention that could be potentially translatable to sepsis survivors as could early access to primary care physician (PCP) follow up. (15, 44, 45) Additionally, a number of interventions that are more tailored to survivors of sepsis could be employed in the future to reduce readmission rates and are summarized below.

Risk Prediction

A potentially key aspect of any readmission reduction initiative would include the ability to identify hospital survivors who are at the greatest risk of readmission for targeted intervention. In the context of the constrained case management and home health resources that many health systems face, the ability to identify such high-risk patients would be of great benefit. A recent systematic review of readmission risk prediction models demonstrated only marginal discriminatory capability for models in most conditions. (46) However, a prospective analysis of prediction models for sepsis survivors has yet to be performed. A number of patient characteristics have now been associated with readmission

in sepsis survivors including age, race, socioeconomic status, comorbidity burden, need for intensive care or procedures, TPN use and anemia (Table 1). In the future, these and other characteristics should be examined to determine their ability to prospectively identify patients at high risk of readmission so that case management resources can be more strategically utilized.

Early Rehabilitation

In recent years, the critical care community has experienced a paradigm shift in the way that critically ill patients undergo physical rehabilitation. In contrast to traditional approaches where patients did not begin physical therapy until they had completely recovered from aspects of their critical illness such as respiratory failure or shock, contemporary practice now consists of beginning early physical therapy, including mobilization, while patients are still critically ill. In a seminal study, investigators demonstrated that early rehabilitation resulted in less delirium, more ventilator free days and higher rates of functional independence at discharge. (47) A subsequent, retrospective analysis identified an association between early rehabilitation and reduced readmission rates. (48) However, this relationship has yet to be prospectively validated and a recent randomized clinical trial (RCT) failed to demonstrate a difference in readmission rates between patients receiving early rehabilitation and usual care while a separate RCT found no difference between 90- and 180-day institution free days. (49, 50) Thus, while early rehabilitation may provide clinical benefit to critical illness survivors, it does not appear to reduce readmission rates, perhaps due to the strong association between readmissions and comorbidity burden which is not impacted by inpatient rehabilitation strategies.

Post-ICU Clinics

Severe sepsis survivors commonly suffer from a wide range of long-term cognitive, physical, and psychiatric sequelae as discussed above. Accordingly, survivors may require outpatient care from a multitude of disciplines including primary care, subspecialty care, physical and occupational therapy, speech therapy and neuro-psychiatry among others. The logistical arrangement of such care can often be problematic for sepsis survivors who may be physically deconditioned and financially limited. The United Kingdom and some centers in the United States have attempted to improve access to this multidisciplinary care through the creation of Post-ICU clinics where critical illness survivors can get comprehensive follow up. (51) To date, there are little to no outcomes data available from this treatment model and its impact on readmission rates is unknown. Future investigation into these clinics' role in reducing preventable readmissions will be a critically important future endeavor.

Future Directions

Although it is impossible to forecast the future, we hope that future work will focus on the role of mobile health technology, palliative care and expanded primary care resources in preventing readmissions among sepsis survivors. Given the near-ubiquitous nature of smart devices (52), mobile health technology is being increasingly leveraged in a variety of clinical settings from medication adherence (53) to chronic disease management. (54) Future applications allowing for symptom monitoring and more accessible outpatient support have the potential to prevent unnecessary readmissions in a variety of populations including

sepsis survivors. However, reduced access to smartphones among survivors with lower socio-economic status may limit this approach's potential in this population. Additionally, given the large co-morbidity burden and debilitation incurred by many sepsis survivors, judicious use of home palliative care and hospice may be a reasonable and appropriate strategy for reducing readmissions in this population. Home palliative care has already been associated with reductions in 30-day readmissions among the seriously ill with profound limitations in functional status (55) and discharge with hospice care is associated with reduced readmission rates among sepsis survivors. (12) Inpatient programs which more effectively engage palliative care consultative services with appropriately selected sepsis survivors may, therefore, be a useful cornerstone of any readmission prevention initiative in this patient population. Finally, as the United States moves toward a capitated pay-for-performance healthcare model, greater emphasis should be placed on preventative outpatient care. Both admissions for and readmissions after sepsis may be positively impacted by increases in primary care resources as emerging data has recently demonstrated that sepsis is an ambulatory care sensitive condition (ACSC). (56, 57) Improved outpatient comorbidity management, in particular, could have significant impact on sepsis readmission rates.

Conclusions

Sepsis survivors suffer from a broad range of cognitive, physical, and psychiatric sequelae; thus, they are a fragile population that experiences rates of readmissions comparable to survivors of CHF, AMI and pneumonia. Sociodemographic, clinical and hospital-level characteristics have all been associated with increased risk of 30-day readmission in this population. Readmissions after sepsis survival lead to additional mortality and cost to the healthcare system and prevention strategies are urgently needed.

Acknowledgments

Sources of Support: NIH/NHLBI 1 K23 HL135263-01A1 and NIH/NIGMS 5 R01 GM113995-03 (A.J.G.); The Duke Endowment Foundation and NIH/NIA 5 R01 AG050698-02 (D.W.F.)

References

1. Adhikari NK, Fowler RA, Bhagwanjee S, Rubenfeld GD. Critical care and the global burden of critical illness in adults. *Lancet*. 2010; 376:1339–1346. [PubMed: 20934212]
2. Martin GS, Mannino DM, Eaton S, Moss M. The epidemiology of sepsis in the united states from 1979 through 2000. *N Engl J Med*. 2003; 348:1546–1554. [PubMed: 12700374]
3. Pfunter AW LM, Steiner C. Costs for hospital stays in the united states, 2011. *HCUP Statistical Brief #168*. 2011
4. Iwashyna TJ, Cooke CR, Wunsch H, Kahn JM. Population burden of long-term survivorship after severe sepsis in older americans. *Journal of the American Geriatrics Society*. 2012; 60:1070–1077. [PubMed: 22642542]
5. Kaukonen KM, Bailey M, Suzuki S, Pilcher D, Bellomo R. Mortality related to severe sepsis and septic shock among critically ill patients in australia and new Zealand, 2000–2012. *JAMA*. 2014; 311:1308–1316. [PubMed: 24638143]
6. Iwashyna TJ, Ely EW, Smith DM, Langa KM. Long-term cognitive impairment and functional disability among survivors of severe sepsis. *JAMA*. 2010; 304:1787–1794. [PubMed: 20978258]
7. Herridge MS, Tansey CM, Matte A, Tomlinson G, Diaz-Granados N, Cooper A, Guest CB, Mazer CD, Mehta S, Stewart TE, Kudlow P, Cook D, Slutsky AS, Cheung AM. Canadian Critical Care

- Trials G. Functional disability 5 years after acute respiratory distress syndrome. *The New England journal of medicine*. 2011; 364:1293–1304. [PubMed: 21470008]
8. Rabiee A, Nikayin S, Hashem MD, Huang M, Dinglas VD, Bienvenu OJ, Turnbull AE, Needham DM. Depressive symptoms after critical illness: A systematic review and meta-analysis. *Crit Care Med*. 2016; 44:1744–1753. [PubMed: 27153046]
 9. Hines AL, Barrett ML, Jiang HJ, Steiner CA. Conditions with the largest number of adult hospital readmissions by payer, 2011: Statistical brief #172. Healthcare cost and utilization project (hcup) statistical briefs. Rockville (MD): 2014.
 10. MEDPAC. Report to congress: Promoting greater efficiency in medicare. 2007
 11. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the medicare fee-for-service program.[erratum appears in n engl j med. 2011 apr 21;364(16): 1582]. *New England Journal of Medicine*. 2009; 360:1418–1428. [PubMed: 19339721]
 12. Goodwin AJ, Rice DA, Simpson KN, Ford DW. Frequency, cost, and risk factors of readmissions among severe sepsis survivors. *Crit Care Med*. 2015; 43:738–746. [PubMed: 25746745]
 13. Ashton CM,MDMPH, Del Junco DJP, Soucek JP, Wray NP,MDMPH, Mansur CLMA. The association between the quality of inpatient care and early readmission: A meta-analysis of the evidence. *Medical Care*. 1997; 35:1044–1059. [PubMed: 9338530]
 14. van Walraven C, Seth R, Austin PC, Laupacis A. Effect of discharge summary availability during post-discharge visits on hospital readmission. *Journal of General Internal Medicine*. 2002; 17:186–192. [PubMed: 11929504]
 15. Hernandez AF, Greiner MA, Fonarow GC, Hammill BG, Heidenreich PA, Yancy CW, Peterson ED, Curtis LH. Relationship between early physician follow-up and 30-day readmission among medicare beneficiaries hospitalized for heart failure. *JAMA*. 2010; 303:1716–1722. [PubMed: 20442387]
 16. van Walraven C, Bennett C, Jennings A, Austin PC, Forster AJ. Proportion of hospital readmissions deemed avoidable: A systematic review. *CMAJ Canadian Medical Association Journal*. 2011; 183:E391–402. [PubMed: 21444623]
 17. Dharmarajan K, Hsieh AF, Lin Z, Bueno H, Ross JS, Horwitz LI, Barreto-Filho JA, Kim N, Bernheim SM, Suter LG, Drye EE, Krumholz HM. Diagnoses and timing of 30-day readmissions after hospitalization for heart failure, acute myocardial infarction, or pneumonia. *JAMA*. 2013; 309:355–363. [PubMed: 23340637]
 18. Centers for medicare and medicaid services. Hospital readmission reduction program (hrrp). 12/21/2017]. Available from: <https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/Readmissions-Reduction-Program.html>
 19. Foundation TKF. Aiming for fewer hospital u-turns: The medicare hospital readmission reduction program. Washington, DC: The Kaiser Family Foundation; 2017.
 20. Axon RN, Williams MV. Hospital readmission as an accountability measure. *JAMA*. 2011; 305:504–505. [PubMed: 21285430]
 21. Benbassat J, Taragin M. Hospital readmissions as a measure of quality of health care: Advantages and limitations. *Archives of internal medicine*. 2000; 160:1074–1081. [PubMed: 10789599]
 22. Keenan PS, Normand SL, Lin Z, Drye EE, Bhat KR, Ross JS, Schuur JD, Stauffer BD, Bernheim SM, Epstein AJ, Wang Y, Herrin J, Chen J, Federer JJ, Mattera JA, Wang Y, Krumholz HM. An administrative claims measure suitable for profiling hospital performance on the basis of 30-day all-cause readmission rates among patients with heart failure. *Circulation Cardiovascular quality and outcomes*. 2008; 1:29–37. [PubMed: 20031785]
 23. Gorodeski EZ, Starling RC, Blackstone EH. Are all readmissions bad readmissions? *New England Journal of Medicine*. 2010; 363:297–298. [PubMed: 20647209]
 24. Krumholz HM, Lin Z, Keenan PS, Chen J, Ross JS, Drye EE, Bernheim SM, Wang Y, Bradley EH, Han LF, Normand SL. Relationship between hospital readmission and mortality rates for patients hospitalized with acute myocardial infarction, heart failure, or pneumonia. *JAMA*. 2013; 309:587–593. [PubMed: 23403683]
 25. Dharmarajan K, Wang Y, Lin Z, Normand ST, Ross JS, Horwitz LI, Desai NR, Suter LG, Drye EE, Bernheim SM, Krumholz HM. Association of changing hospital readmission rates with mortality rates after hospital discharge. *JAMA*. 2017; 318:270–278. [PubMed: 28719692]

26. Heggestad T. Do hospital length of stay and staffing ratio affect elderly patients' risk of readmission? A nation-wide study of norwegian hospitals. *Health services research*. 2002; 37:647–665. [PubMed: 12132599]
27. Carey K, Lin MY. Hospital length of stay and readmission: An early investigation. *Medical care research and review : MCRR*. 2014; 71:99–111. [PubMed: 24132581]
28. Ansari SF, Yan H, Zou J, Worth RM, Barbaro NM. Hospital length of stay and readmission rate for neurosurgical patients. *Neurosurgery*. 2017
29. Kaboli PJ, Go JT, Hockenberry J, Glasgow JM, Johnson SR, Rosenthal GE, Jones MP, Vaughan-Sarrazin M. Associations between reduced hospital length of stay and 30-day readmission rate and mortality: 14-year experience in 129 veterans affairs hospitals. *Ann Intern Med*. 2012; 157:837–845. [PubMed: 23247937]
30. Marcantonio ER, McKean S, Goldfinger M, Kleefield S, Yurkofsky M, Brennan TA. Factors associated with unplanned hospital readmission among patients 65 years of age and older in a medicare managed care plan. *The American journal of medicine*. 1999; 107:13–17. [PubMed: 10403347]
31. Tully PJ, Baker RA, Turnbull D, Winefield H. The role of depression and anxiety symptoms in hospital readmissions after cardiac surgery. *Journal of behavioral medicine*. 2008; 31:281–290. [PubMed: 18398676]
32. Prescott HC, Langa KM, Liu V, Escobar GJ, Iwashyna TJ. Increased 1-year healthcare use in survivors of severe sepsis. *Am J Respir Crit Care Med*. 2014; 190:62–69. [PubMed: 24872085]
33. Liu V, Lei X, Prescott HC, Kipnis P, Iwashyna TJ, Escobar GJ. Hospital readmission and healthcare utilization following sepsis in community settings. *Journal of hospital medicine*. 2014; 9:502–507. [PubMed: 24700730]
34. Donnelly JP, Hohmann SF, Wang HE. Unplanned readmissions after hospitalization for severe sepsis at academic medical center-affiliated hospitals. *Crit Care Med*. 2015; 43:1916–1927. [PubMed: 26082977]
35. Chang DW, Tseng CH, Shapiro MF. Rehospitalizations following sepsis: Common and costly. *Crit Care Med*. 2015; 43:2085–2093. [PubMed: 26131597]
36. Jones TK, Fuchs BD, Small DS, Halpern SD, Hanish A, Umscheid CA, Baillie CA, Kerlin MP, Gaieski DF, Mikkelsen ME. Post-acute care use and hospital readmission after sepsis. *Annals of the American Thoracic Society*. 2015; 12:904–913. [PubMed: 25751120]
37. Sun A, Netzer G, Small DS, Hanish A, Fuchs BD, Gaieski DF, Mikkelsen ME. Association between index hospitalization and hospital readmission in sepsis survivors. *Crit Care Med*. 2016; 44:478–487. [PubMed: 26571185]
38. Joynt KE, Orav EJ, Jha AK. Thirty-day readmission rates for medicare beneficiaries by race and site of care. *JAMA*. 2011; 305:675–681. [PubMed: 21325183]
39. Mayr FB, Talisa VB, Balakumar V, Chang CH, Fine M, Yende S. Proportion and cost of unplanned 30-day readmissions after sepsis compared with other medical conditions. *JAMA*. 2017; 317:530–531. [PubMed: 28114505]
40. DeMerle KM, Royer SC, Mikkelsen ME, Prescott HC. Readmissions for recurrent sepsis: New or relapsed infection? *Crit Care Med*. 2017; 45:1702–1708. [PubMed: 28742549]
41. Prescott HC. Variation in postsepsis readmission patterns: A cohort study of veterans affairs beneficiaries. *Annals of the American Thoracic Society*. 2017; 14:230–237. [PubMed: 27854510]
42. Faust JS, Weingart SD. The past, present, and future of the centers for medicare and medicaid services quality measure sep-1: The early management bundle for severe sepsis/septic shock. *Emergency medicine clinics of North America*. 2017; 35:219–231. [PubMed: 27908335]
43. Ahmad FS, Metlay JP, Barg FK, Henderson RR, Werner RM. Identifying hospital organizational strategies to reduce readmissions. *American journal of medical quality : the official journal of the American College of Medical Quality*. 2013; 28:278–285. [PubMed: 23118202]
44. Kilcup M, Schultz D, Carlson J, Wilson B. Postdischarge pharmacist medication reconciliation: Impact on readmission rates and financial savings. *Journal of the American Pharmacists Association : JAPhA*. 2013; 53:78–84. [PubMed: 23636160]
45. Giordano A, Scalvini S, Zanelli E, Corra U, Longobardi GL, Ricci VA, Baiardi P, Glisenti F. Multicenter randomised trial on home-based telemanagement to prevent hospital readmission of

- patients with chronic heart failure. *International journal of cardiology*. 2009; 131:192–199. [PubMed: 18222552]
46. Kansagara D, Englander H, Salanitro A, Kagen D, Theobald C, Freeman M, Kripalani S. Risk prediction models for hospital readmission: A systematic review. *JAMA*. 2011; 306:1688–1698. [PubMed: 22009101]
47. Schweickert WD, Pohlman MC, Pohlman AS, Nigos C, Pawlik AJ, Esbrook CL, Spears L, Miller M, Franczyk M, Deprizio D, Schmidt GA, Bowman A, Barr R, McCallister KE, Hall JB, Kress JP. Early physical and occupational therapy in mechanically ventilated, critically ill patients: A randomised controlled trial. *Lancet*. 2009; 373:1874–1882. [PubMed: 19446324]
48. Morris PE, Griffin L, Berry M, Thompson C, Hite RD, Winkelman C, Hopkins RO, Ross A, Dixon L, Leach S, Haponik E. Receiving early mobility during an intensive care unit admission is a predictor of improved outcomes in acute respiratory failure. *The American journal of the medical sciences*. 2011; 341:373–377. [PubMed: 21358312]
49. Morris PE, Berry MJ, Files DC, Thompson JC, Hauser J, Flores L, Dhar S, Chmelo E, Lovato J, Case LD, Bakhru RN, Sarwal A, Parry SM, Campbell P, Mote A, Winkelman C, Hite RD, Nicklas B, Chatterjee A, Young MP. Standardized rehabilitation and hospital length of stay among patients with acute respiratory failure: A randomized clinical trial. *JAMA*. 2016; 315:2694–2702. [PubMed: 27367766]
50. Moss M, Nordon-Craft A, Malone D, Van Pelt D, Frankel SK, Warner ML, Kriekels W, McNulty M, Fairclough DL, Schenkman M. A randomized trial of an intensive physical therapy program for patients with acute respiratory failure. *Am J Respir Crit Care Med*. 2016; 193:1101–1110. [PubMed: 26651376]
51. Griffiths JA, Barber VS, Cuthbertson BH, Young JD. A national survey of intensive care follow-up clinics. *Anaesthesia*. 2006; 61:950–955. [PubMed: 16978309]
52. Mobile fact sheet. 2017. 10/11/2017]. Available from: <http://www.pewinternet.org/fact-sheet/mobile/>
53. Pop-Eleches C, Thirumurthy H, Habyarimana JP, Zivin JG, Goldstein MP, de Walque D, MacKeen L, Haberer J, Kimaiyo S, Sidle J, Ngare D, Bangsberg DR. Mobile phone technologies improve adherence to antiretroviral treatment in a resource-limited setting: A randomized controlled trial of text message reminders. *Aids*. 2011; 25:825–834. [PubMed: 21252632]
54. Sieverdes JC, Treiber F, Jenkins C. Improving diabetes management with mobile health technology. *The American journal of the medical sciences*. 2013; 345:289–295. [PubMed: 23531961]
55. Ranganathan A, Dougherty M, Waite D, Casarett D. Can palliative home care reduce 30-day readmissions? Results of a propensity score matched cohort study. *Journal of palliative medicine*. 2013; 16:1290–1293. [PubMed: 24007348]
56. Goodwin AJ, Nadig NR, McElligott JT, Simpson KN, Ford DW. Where you live matters: The impact of place of residence on severe sepsis incidence and mortality. *Chest*. 2016; 150:829–836. [PubMed: 27445093]
57. Prescott HC, Langa KM, Iwashyna TJ. Readmission diagnoses after hospitalization for severe sepsis and other acute medical conditions. *JAMA*. 2015; 313:1055–1057. [PubMed: 25756444]

Table 1

Risk Factors for 30 day hospital readmissions after survival of sepsis

Risk Factors	Adjusted Odds Ratio (95% C.I.)	Reference
Patient Demographics		
Black race	1.29 (1.24–1.33)	(12, 34)
Native American race	2.39 (1.79–3.19)	(34)
Lower income	1.13 (1.10–1.16)	(34)
Female race	0.92 (0.87–0.96), 1.03 (1.01–1.05)	(12, 33)
Medicare	1.21 (1.13–1.30)	(12, 33)
Medicaid	1.34 (1.23–1.46)	(12, 33)
Age (10 year increase)	0.94 (0.89–0.99)	(35)
Age < 80 years	1.14 (1.08–1.21)	(12)
Patient Co-morbidities		
Any malignancy	1.34 (1.24–1.45), 1.79 (1.47–2.19)	(12, 35)
Collagen vascular disease	1.30 (1.15–1.46)	(12)
Chronic kidney disease	1.24 (1.18–1.31)	(12)
Liver disease	1.22 (1.11–1.34)	(12)
Congestive heart failure	1.14 (1.08–1.19)	(12)
Chronic lung disease	1.12 (1.06–1.18)	(12)
Diabetes mellitus	1.12 (1.07–1.17)	(12)
Hospitalization in the past year	1.56 (1.30–1.86); 2.12 (1.28–3.53)	(35, 36)
Index Hospitalization Characteristics		
Requires Intensive Care	1.21 (1.05–1.40)	(32)
Hospital length of stay (days)	1.01 (1.00–1.02)	(12, 32, 33)
Procedure performed	1.64 (1.24–2.16)	(35)
Anemia on discharge	1.48 (1.24–1.75)	(35, 36)
Use of total parenteral nutrition	3.11 (1.56–6.20)	(36)
Discharge to care facility	1.48 (1.40–1.56)	(12)
Index Hospital Characteristics		
High proportion of minority patients	1.28 (1.23–1.34)	(34)
For profit	1.34 (1.31–1.38)	(34)
University hospital	1.35 (1.26–1.44)	(33, 34)
Annual sepsis case volume (by quartile)	1.07 (1.03–1.12)	(12, 33)

Odds ratios are presented wherever they are available in the reference

Table 2

Peri-discharge processes and interventions that may impact readmission rates

Process/Intervention	Study Design(s)	Findings
Medication reconciliation	Randomized clinical trial	Post-discharge phone call (day 3–7) for medication reconciliation resulted in reduced 7-day and 14-day readmissions. No change in 30-day readmissions.
Improved access to primary care		
Enhanced follow up by PCP	Randomized clinical trial	Providing enhanced PCP follow up to a chronically ill veteran population had no reduction in 6 month readmissions.
Earlier Follow up with PCP	Observational cohort	Readmission rates are lowest in hospitals with the highest proportion of early follow-up visits among Medicare patients admitted with CHF.
Availability of discharge summary	Observational cohort	Trend toward reduced readmission rates if a discharge summary was available at the time of the post-discharge follow-up visit.
Telehealth		
Phone interviews/ECG monitoring	Randomized clinical trial	Weekly phone calls and ECG analysis reduced one year readmission rates among patients admitted with CHF.
Telemetric hemodynamic monitoring	Randomized clinical trial	Outpatient care guided by telemetry data from implanted pulmonary artery monitors reduced heart failure related hospitalizations.

PCP = Primary Care Physician, ECG = Electrocardiogram, CHF = Congestive Heart Failure