BMJ Open

Very sick and very costly; a systematic review of high-cost patients' drivers of healthcare utilization

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-023113
Article Type:	Research
Date Submitted by the Author:	21-Mar-2018
Complete List of Authors:	Wammes, Joost Van der Wees, Philip; Radboud University Medical Centre, Nijmegen, IQ healthcare Tanke, Marit; IQ Healthcare / Celsus academy for sustainable healthcare Westert, Gert; Radboud university medical centre, Scientific Institute for Quality of Healthcare (IQ Healthcare Jeurissen, Patrick; Radboud Universiteit, IQ healthcare / Celsus academy for sustainable healthcare
Keywords:	HEALTH SERVICES ADMINISTRATION & MANAGEMENT, high-need high-cost, integrated delivery of health care, health care utilization, health care costs

Very sick and very costly; a systematic review of high-cost patients' drivers of healthcare utilization

Joost Johan Godert Wammes[1], MSc
Radboud university medical center, Scientific Center for Quality of Healthcare / Celsus academy for sustainable healthcare. Nijmegen, the Netherlands.

Philip J van der Wees, PhD
Radboud university medical center, Scientific Center for Quality of Healthcare / Celsus academy for sustainable healthcare. Nijmegen, the Netherlands.
Philip.vanderwees@radboudumc.nl

Marit AC Tanke, MD, PhD
Radboud university medical center, Scientific Center for Quality of Healthcare / Celsus academy for sustainable healthcare. Nijmegen, the Netherlands. Marit.tanke@radboudumc.nl

Gert P Westert, PhD
Radboud university medical center, Scientific Center for Quality of Healthcare. Nijmegen, the Netherlands. Gert.westert@radboudumc.nl

Patrick PT Jeurissen, PhD
Radboud university medical center, Scientific Center for Quality of Healthcare / Celsus academy for sustainable healthcare. Nijmegen, the Netherlands.
Patrick.jeurissen@radboudumc.nl

1 Corresponding author:
Joost Wammes, MSc
Radboud university medical center, Scientific Center for Quality of Healthcare / Celsus academy for sustainable healthcare.
Address: P.O. Box 9101, 6500 HB Nijmegen, the Netherlands.
Phone: +31-24-361 6359,
Fax: +31-24-354 0166
Email: joost.wammes@radboudumc.nl

Article summary section

Abstract

Objectives: To investigate the characteristics and healthcare utilization of high-cost patients, and to compare high-cost patients across payers and countries.

Design: Systematic review.

Data sources: Pubmed and Embase databases were searched until October 30th, 2017.

Eligibility criteria and outcomes: Our final search was built on three themes: 'high-cost', 'patients', and 'cost' and 'cost analysis'. We included articles that reported characteristics and utilization of the top-X% (e.g. top-5%, top-10%) patients of costs of a given population. Analyses were limited to studies that covered a broad range of services, across the continuum of care. Andersen's behavioral model was used to categorize characteristics and determinants into predisposing, enabling and need characteristics.

Results: The studies pointed to a high prevalence of multiple (chronic) conditions to explain high-cost patients' utilization. Besides, we found a high prevalence of mental illness across all studies, most notably in US Medicaid and total population studies. Preventable spending was estimated at maximally ten percent of spending. Furthermore, we found that high costs were associated with increasing age, but that still more than halve of high-cost patients were younger than 65. High costs were associated with higher incomes in the US, but with lower incomes elsewhere. Finally, we confirmed that high-cost patients are more likely to die, and decedents are more likely to incur high-costs. However, no more than 30% of high-cost patients are in their last year of life.

Conclusions: High-cost patients make up the sickest and most complex populations and their high utilization is primarily explained by high levels of chronic and mental illness. High-cost patients are diverse populations and vary across payer types and countries. Tailored

interventions are needed to meet the needs of high-cost patients, and to avoid waste of scarce resources.

Key words: health services administration and medicine; high-need high-cost; integrated delivery of health care; health care utilization, health care costs

Word count: 3,992

Strengths and limitations of this study

- This study provides a comprehensive review of high-cost patients' characteristics and healthcare utilization.
- Grey literature was not included in our systematic review. However, we identified 46 studies and compared high-cost patients' characteristics and healthcare utilization across payers and countries.
- We did not assess the quality of the studies because of the methodological diversity of the studies.

Background

It is widely known that healthcare costs are concentrated among a small group of 'high-cost' patients[1]. Although they receive substantial care from multiple sources, critical health care needs are unmet, and many receive unnecessary and ineffective care[2-5]. This suggests that high-cost patients are a logical group to seek for quality improvement and cost reduction.

Especially in the US, many providers or insurance plans have pursued this logic and developed programs for "high-need, high-cost patients". So far, such programs, including for example care coordination and disease management, have had favorable results in quality of care and health outcomes, and mixed results in their ability to reduce hospital use and costs[6]. Research has shown that the effectiveness and efficiency of the programs increase when interventions are targeted to the patients that most likely benefit[2, 7, 8]. Little is known however, about variations in clinical characteristics and care-utilization patterns across payer-defined groups or countries[9]. Such insight in the health requirements of high-cost patients is prerequisite for designing effective policy or program responses.

We conducted this systematic review to synthesize the literature on high-cost patients' characteristics and healthcare utilization. Andersen's behavioral model (see method section) was used to organize the findings. Our analysis was aimed at identifying drivers of costs that matter across payer types and countries. We aimed to inform the development of new interventions and policy, as well as future research in high-cost patients.

Methods

Our methodology was based on established guidance for conducting systematic reviews[10, 11]. Our main research questions was 'Who are the most expensive patients, what health care services do they use, what drives these high costs, and what drivers matter across payers and countries?'.

Study selection

A preliminary search in Pubmed was conducted to identify key articles. On the basis of these findings, we developed a search strategy covering the most important terms. We then reshaped the search strategy by consulting an information specialist of our university. The final search was built on three themes: 'high-cost', 'patients', and 'cost' and 'cost analysis'. We searched Pubmed and Embase at October 30th, 2017. Full details of our search strategy are attached in appendix 1.

Inclusion and exclusion criteria

Articles were reviewed by Author A using title and abstract to identify potentially eligible studies. Author B verified a random sample of articles to guarantee specificity and sensitivity of the selection process. Only studies from high-income countries - as defined by the World Bank[12] – were included. Studies not written in English and conference abstracts were excluded. In the second step, titles and abstracts were reviewed by Author A to assess whether articles fit within our definition of high-cost patients: the article reported characteristics and utilization of the top-X% (e.g. top-5%, top-10%) patients of costs of a given population. Author B verified a random sample of articles at this selection step. In the third step, full-text articles were retrieved and independently screened by Author A and Author B for our inclusion criteria. At this step, we aimed for studies covering a broad range

of services across the continuum of care at health system level, and excluded all studies with a narrow scope of costs (for example: hospital costs, pharmaceutical costs) and all studies with a narrow population base (primarily disease oriented studies, or studies in children).

[Figure 1. Selection process.]

Data extraction

A data extraction form was developed by the research team to ensure the approach was consistent with the research question. Author A extracted all data. To guarantee specificity and sensitivity of data extraction, Author B and Author C both independently extracted the data of five random articles. A meeting was held to discuss (in-)consistencies in extraction results. Per article the following key elements were extracted: author, year, country, definition of high-cost patients, in- and exclusion criteria of the study population, cost data used to determine total costs, characteristics of the high-cost patients such as diagnoses, age, gender, ethnicity, determinants for high costs including associated supply side factors (concerning the supply of health services), subpopulations, and health care use and costs (per subpopulation). To identify the most important medical characteristics, only those diseases with a high prevalence (≥10%) among high-cost patient populations or medical characteristics overrepresented in high-cost populations were extracted. Medical characteristics (prevalent diseases) were categorized and presented at the level of ICD10-chapters.

Data synthesis

Andersen's behavioral model was used to categorize characteristics and determinants for high costs into predisposing, enabling and need characteristics. Andersen's model assumes that healthcare use is a function of 1) characteristics that *predispose* people to use or not to use services, although such characteristics are not directly responsible for use (e.g. age, gender,

education, ethnicity, beliefs) 2) *enabling* characteristics that facilitate or impede use of services (income/wealth/insurance as ability to pay for services, organization of service provision, health policy) 3) *needs* or conditions that laypeople or health care providers recognize as requiring medical treatment. The model also distinguishes between individual and contextual (measured at aggregate level, such as measures of community characteristics) determinants of service use. Andersen hypothesized that the variables would have differential ability to explain care use, depending on the type of service. For example, dental care (and other discretionary services) would be explained by predisposing and enabling characteristics, whereas hospital care would primarily be explained by needs and demographic characteristics[13, 14].

We presented all data according to five general categories, including study characteristics, predisposing characteristics, enabling characteristics, need characteristics, and expenditure categories and health care utilization. We presented summary tables of results, extracted central themes and topics from the studies, and summarized them narratively. All studies were analyzed according to payer and country to identify the most important drivers across settings.

Results

General information

Our search strategy resulted in 7905 articles. After first broad eligibility assessment 767 articles remained. After screening of titles and abstracts, 190 articles remained for full-text screening, from which 46 were ultimately included (figure 1).

A description of the studies is given in table 1. The majority of the studies were conducted in the United States (N=35). The remaining studies were conducted in Canada (N=8), Denmark (N=1), the Netherlands (N=1), and Taiwan (N=1). Three studies were published before the year 2000. All were retrospective cohort studies, and descriptive and logistic regression analysis were the main analytic approaches used. The study period ranged from one to thirty years. The most frequent observation period was one year.

A range of definitions for high-cost patients were used, and some studies used more than one definition to distinguish between age groups, between high- and very high-cost patients, or to study persistently high-cost patients (>1 year high costs). In general, patients belonging to the top-1%, top-5%, top-10%, or top-20% of spending were considered high-cost patients.

The study population differed between the studies. We categorized fourteen studies as 'total population' studies, including studies in universal insurance schemes (of all ages; eight Canadian studies, one Dutch and one Danish study), studies that combined data of different payers, or survey studies. Respectively nine, six and ten studies were among US Medicare, US Medicaid or US commercial populations. The remaining studies compared high-cost patients in multiple US payers, or were among US dual eligibles (eligible for both Medicare and Medicaid), US Veterans Affairs (VA)-beneficiaries, or among elderly in the Taiwanese insurance system. Some studies used additional criteria to determine the population. Age,

healthcare use, or insurance were most frequently used as secondary condition to determine the population.

In 43 studies, total costs per patient were based on the insurance plan or public program. In the remaining studies, total costs were based on a survey or identified from a variety of sources.

Predisposing characteristics

Table 2 presents predisposing, enabling and need characteristics associated with high-cost patients. Age was related to high-cost patients in several ways. First, high-cost patients were generally older, and higher age was associated with high costs. This held for each payer type. Second, persistently high-cost patients were generally older than episodic high-cost patients, and higher ages were associated with persistently high costs. Third, the magnitude of cost concentration, and the threshold for high costs differed between age groups[15]. As younger groups are generally healthier, costs are concentrated among fewer individuals. Fourth, clinical diagnoses and utilization patterns varied across age groups[15-17], and some subgroups were related to particular ages, including mental health high-cost patients among younger ages[18]. Finally, although age was related to high costs, total population studies showed that approximately half of the high-cost populations were younger than 65[17, 19].

Studies showed inconsistent results for gender. Respectively 7 and 15 studies noted males and females were overrepresented in high-cost patients. Besides, gender was associated with different segments of the high-cost population, including males in top-1% or persistently extreme-cost patients, and females in top-2-5% or persistently high-cost patients[17, 20, 21], or males in mental health high-cost patients[18].

Ten studies reported the association between ethnicity and high costs. In two Canadian total population studies and three US Medicaid studies whites were overrepresented among

high-cost populations, whereas in five US Medicare studies Blacks or non-Whites were overrepresented.

Socioeconomic status is regarded as both a predisposing characteristic and an enabling characteristic in Andersen's model, and we found evidence for both relationships. One Canadian study found that high costs were most strongly associated with food insecurity, lower personal income, non-homeownership and living in highly deprived or low ethnic concentration neighborhoods[22].

Ganguli et al studied health beliefs among high-cost US Medicare patients: socioeconomic status, social network, patient activation, and relationships with and trust in the clinician and the health system all increased or decreased costs, depending on the context. Trust was particularly important, and modified the interaction between patient activation and costs: when patients trusted their physicians, patient activation was associated with lower costs. When trust was lacking, patient activation was associated with higher costs[23].

Health behaviors, including underweight, obesity, physical inactivity and former smoking were significantly related to high costs[24].

Enabling characteristics

The studies' abilities to assess the effect of insurance were limited because most study populations were determined by insurance. Nevertheless, the studies indicated that increased insurance may have indicated specific or additional care needs. For example, six US Medicare studies reported that high-cost patients were more likely dually eligible and four US Medicaid studies reported that certain eligibility statuses were associated with high costs. In addition, increased insurance was associated with high costs because it lowers costs. Two US commercial studies mentioned that high-cost patients were more likely to have a health maintenance organization plan, a preferred provider organization plan, or comprehensive

insurance compared to high-deductible health plans; and insured status was associated with less consideration of costs in decision making[23].

Eleven studies addressed the relationship between income and high costs. In three US studies higher incomes were associated with high costs, whereas four Canadian studies found that lower incomes were associated with (mental health) high costs. However, one US, one Taiwanese, and one Canadian study reported that income was not significantly related to high costs. Finally, among high-cost US Medicare patients, personal resources and education were associated with increased use of resources (higher SES was linked to higher priced care), but also with lower resources use[23].

Organizational enabling factors

The number of primary care physicians, specialists and hospital beds were associated with higher per capita preventable costs among high-cost US Medicare patients[25]. In contrast, Garfinkel et al found that the probability of high-cost decreased when the physician-to-population ratio increased for people aged between 17 and 64 years[26]. Reschovsky et al found several weak or insignificant relationships between organizational factors and high costs within the high-cost population, but found that high-cost US Medicare patients more likely had a medical specialist as usual source of care than a primary care physician or surgeon[27]. Finally, high-cost US Medicare patients were only modestly concentrated in hospitals and markets (they were widely distributed through the system). High concentration hospitals (with relatively many high-cost patients) had a 15% higher median cost per claim, were more likely for-profit and teaching hospitals, had lower nurse-to-patient ratios, were more likely to care for the poor, and had higher 30-day readmission rates and lower 30-day mortality rates. High concentration hospital referral regions had higher annual median costs per beneficiary, a larger supply of specialists but equal supply of total physicians, a lower

supply of long term care beds, higher hospital care intensity and higher end-of-life spending[28].

Need characteristics

Medical characteristics of high-cost patients are presented in table 2. We categorized medical characteristics to ICD10-chapters. Circulatory diseases, mental and behavioral disorders, endocrine, nutritional and metabolic, diseases of the respiratory system, diseases of the genitourinary system, neoplasms and diseases of the musculoskeletal system and connective tissue were most frequently reported among high-cost patients. The prevalence of chronic disease(s) and multimorbidity were also dominant among high-cost patients. For example, Bynum et al showed that over 26.4% of high-cost US dual eligibles suffered from five or more chronic conditions[16].

Two studies presented medical characteristics across US payers. Both studies showed that high-cost commercial patients had the lowest numbers of comorbidities and that high-cost Medicaid patients had the highest prevalence of mental illness[9, 29]. We further compared the prevalence of diabetes, congestive heart failure, lung disease, and mental disorders across the studies. The prevalence of diabetes, congestive heart failure and lung disease was relatively low (≈5%-25%) in US commercial and total population studies. In US Medicaid, the prevalence of congestive heart failure and lung disease were relatively high (≈15%-40%; one study reported a prevalence of diabetes and lung disease > 60%[30]), and the prevalence of mental illness was particularly high (≈30%-75%). In US Medicare, the prevalence of diabetes, congestive heart failure and lung disease were highest (≈20%-55%) and the prevalence of mental illness more modest (≈10%-25%). In total populations, approximately 30-40% of high-cost patients were treated for mental illness. Finally, persistent high-cost

patients had a higher number of comorbidities and a higher prevalence of each of the diseases compared to episodic high-cost patients.

High-cost patients were more likely to die, and those in the process of dying were more likely to incur high costs. The mortality differed between payers, much less between countries. In US Medicare studies the mortality ranged from 14.2% to 27.4%, compared to 11.7% in one US Medicaid study and 5% to 13% in total populations. In addition, top-1% patients were more likely to die compared to top-5% patients[17, 31] and persistent high-cost patients were more likely to die than episodic high-cost patients[32]. Finally, among US dual eligibles, mortality varied much across age and residence groups; nearly half of dual eligibles aged 65 and older died[16].

Expenditure patterns and healthcare utilization

In each study, costs were heavily concentrated. The top-10% patients roughly accounted for about 68% of costs (range: 55%-77%), the top-5% patients accounted for about 55% of costs (range: 29%-65%) and top-1% patients for approximately 24% (range: 14%-33%) within a given year. Costs were generally less concentrated in US Medicare, and more concentrated in total populations.

A wide range of parameters were used to describe high-cost patients' healthcare utilization (table 3). Inpatient acute hospital care was most often reported as a primary expenditure category for high-cost patients. In line with this, seventeen studies reported hospitalizations, admissions or inpatient days as important cost drivers. Lieberman found that total spending per beneficiary correlated strongly with the use of inpatient services[33], likewise several studies found that increasing levels of use (i.e. top-1% compared to top-5%) were associated with increasing proportions of spending on (inpatient) hospital care[17, 20, 23, 24, 34-36]. Guo et al reported that high-cost users consumed more units of each of the

service category analyzed, with the exception of laboratory tests[37]; these findings were confirmed elsewhere[20, 35, 38]. In addition, it was found that 91% of high-cost patients received care in multiple care types[39]. Mental care services were listed as expenditure category only in studies of total populations, US Medicaid, and US VA. Finally, one study determined the frequency use of expensive services among high-cost patients: expensive treatments (expensive drugs, intensive care unit treatment, dialysis, transplant care, and DRGs >€30,000) contributed to high cost in approximately one third of top-1% patients, and in less than ten percent of top-2-5% patients[17].

Four studies quantified the amount of 'preventable' spending (based on preventable emergency department visits and preventable (re-)admissions) among high-cost patients. As shown above, various supply side characteristics were associated with higher preventable costs among high-cost US Medicare patients, and approximately 10% of total costs were preventable[25]. Another study found that 4.8% of US Medicare spending was preventable, and that high-cost patients accounted for 73.8% of preventable spending. Moreover, 43.8% of preventable spending was accounted for by frail elderly, and preventable spending was particularly high for heart failure, pneumonia, COPD/asthma and urinary tract infections[40]. Figueroa et al found that preventable spending differed by insurance type among US non-elderly: respectively 3,5%, 2.8% and 1.4% of spending were preventable among US Medicaid, US Medicaid managed care and privately insured high-cost patients[30]. Similarly, Graven et al found that proportions of preventable spending differed between payers, and that persistent high-cost patients had higher proportions of preventable spending[29].

Twenty studies reported on the persistency of high costs. We found three approaches for studying persistency. First, studies reported *prior* healthcare use and/or reported *posterior* healthcare use for patients with high costs in a given index year. In other studies, persistent high-cost patients were compared to episodic high-cost patients. Spending persistency varied

between 24% and 48% for top-5% patients, and between 28% and 45% for top-10% patients. Spending persistence was relatively high in US Medicaid, and relatively low in US Medicare. Increasing persistence was associated with increasing expenditures on all service types[38].

Discussion

We reviewed 46 studies on high-cost patients' characteristics and healthcare utilization, and made comparisons across payers and countries. The studies consistently point to a high prevalence of multiple (chronic) conditions to explain high-cost patients' utilization. Besides, we found a high prevalence of mental illness across all the studies, most notably in US Medicaid and total population studies. We found that various health system characteristics may contribute to high costs. Preventable spending was estimated at maximally ten percent of spending. Furthermore, we found that high costs are associated with increasing age and that clinical diagnoses and utilization patterns varied across age groups. However, still more than half of high-cost patients are younger than 65 years. High costs were associated with higher incomes in the US, but with lower incomes elsewhere. Finally, we confirmed that high-cost patients are more likely to die, and decedents are more likely to incur high-costs. However, no more than 30% of high-cost patients were in their last year of life.

Strengths and weaknesses

This is the first systematic review of scientific literature on high-cost patients' characteristics and healthcare utilization. Future studies might consider inclusion of grey literature. We included studies of various payer types and countries, allowing comparisons across settings. However, most studies were conducted in the United States and Canada, which limits the generalisability of the findings. One limitation is that we, because of methodological diversity, did not assess the quality of the included studies, and some studies by design did not

control for confounding. Finally, the studies used various approaches for defining the needs and measuring multimorbidity among their populations, which limits the comparability across studies.

Reflections on our findings

Our review highlighted notable differences in characteristics and utilization across payers and countries. This (clinical) diversity of high-cost patients may even be larger at a local level. Segmentation analysis has been suggested as a method to identify homogenous and meaningful segments of patients with similar characteristics, needs and behavior, that allows for tailored policy[41]. Given the multiple needs and cross-sectoral utilization of high-cost patients, we suggest such analyses should capture both characteristics and utilization as broadly as possible, to fully apprehend high-cost patients care needs and utilization. In the context of high-cost patients, multimorbidity complicates segmentation, and the usefulness of segmentation may depend on the way multimorbidity is dealt with. To illustrate a potent example, Hayes et al defined high-need, high-cost patients as "people having three or more chronic conditions and a functional limitation that makes it hard for them to perform basic daily tasks"[42].

Our findings also reveal several supply side factors that contribute to high costs. However, no firm conclusions can be drawn about the strength of these effects. The apparent limited impact of organizational factors on spending is in line with Andersen's model predictions, where multimorbidity and health status are prime determinants of healthcare costs[43]. However, such findings are surprising given the abundance of evidence for supplier induced demand and medical practice variation[44]. High-cost populations may be too diverse for studying the impact of organizational factors; for such studies more homogenous populations may be prerequisite.

Four of our included studies estimated the amount of 'preventable' spending among high-cost patients. Preventable spending was estimated at maximally ten percent of spending, which is relatively low compared to the amounts of savings that have been reported elsewhere[8]. Preventable spending was mainly defined as preventable emergency department visits or preventable (re-)admissions, as such echoing the two primary targets of most high-need high-cost programs, including care coordination and disease management. The algorithms used were said to be relatively narrow and could have included other diagnostic categories[29]. Besides, future studies might consider more broad measures of preventable or wasteful spending, and develop algorithms to identify duplicate services, contra-indicated care, unnecessary laboratory testing, unnecessary prolonged hospitalizations, or any other kinds of lower value services.

It was striking that three US studies reported that higher incomes were associated with high costs, whereas other studies found that lower incomes were associated with high costs. These findings may point to disparities in health, the price that some Americans pay for their care, and the reduced accessibility to care of low income patients. This may particularly hold for the uninsured. Besides, these findings suggest tailored interventions for lower income patients may be worthwhile.

Policy and research implications

We identified four major segments of high-cost patients, including patients in their last year of life, patients experiencing a significant health event who return to stable health (episodically high-cost patients), patients with mental illness, and patients with persistently high costs characterized by chronic conditions, functional limitations and elder age.

Many interventions have been taken to increase value of end-of-life care. Advance care planning has shown to increase the quality of end-of-life care and decrease costs[45-47].

In addition, health systems might consider strengthening their palliative care systems[48]. Increasing value for episodically high-cost patients requires appropriate pricing of procedures and drugs, for example through selective contracting of providers, reference pricing or competitive bidding[49]. In addition, bundled payments for procedures and associated care may improve care coordination and reduce the use of duplicative or unnecessary services[50]. Multidisciplinary needs assessment and shared decision making may reduce unwarranted variation in expensive procedures. Mental health high-cost patients are known for their medical comorbidities, which suggests these patients might benefit from multidisciplinary cross-sectoral healthcare delivery, for example through collaborative care[51, 52]. Finally, persistent high-cost patients might benefit from a variety of models, including disease management, care coordination, or ambulatory intensive care units, depending on the needs of the population and local circumstances[8, 53-55].

One study addressed health beliefs and patient networks among high-cost patients[23]. More of such research is needed as health beliefs may be more amenable to change than other drivers of high costs. One study analyzed the use of expensive treatments by high-cost patients[17]. Better insight in such healthcare utilization patterns is needed to inform interventions and policy aimed at high-cost populations. There is a need for segmentation variables and logic that is informative at either micro-, meso- and macrolevel. More research is needed to identify determinants of preventable and wasteful spending.

In conclusion, high-cost patients make up the sickest and most complex populations and their high utilization is primarily explained by high levels of chronic and mental illness. High-cost patients are diverse populations and vary across payer types and countries. Tailored interventions are needed to meet the needs of high-cost patients, and to avoid waste of scarce resources.

Acknowledgements: None.

Author contributions: JW drafted the first manuscript and conducted the analyses. JW and PvdW selected eligible studies. JW, PvdW and MT conceptualized the study and interpreted the data. GW and PJ made a substantial contribution to the development of the research question and interpretation and presentation of the findings. All authors provided feedback to, and approved the final manuscript.

Funding statement: The study was conducted as part of a research program funded through the Dutch Ministry of Health. The funding source had no role in study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the manuscript for publication.

Competing interests: None.

Data sharing statement: Detailed forms with extracted data are available from the authors upon request.

References

1. Zook, C.J. and F.D. Moore, *High-cost users of medical care.* N Engl J Med, 1980. **302**(18): p. 996-1002.
2. Blumenthal, D., et al., *Caring for High-Need, High-Cost Patients - An Urgent Priority.* N Engl J Med, 2016. **375**(10): p. 909-11.
3. Bodenheimer, T. and A. Fernandez, *High and rising health care costs. Part 4: can costs be controlled while preserving quality?* Ann Intern Med, 2005. **143**(1): p. 26-31.
4. Colla, C.H., et al., *Association Between Medicare Accountable Care Organization Implementation and Spending Among Clinically Vulnerable Beneficiaries.* JAMA Intern Med, 2016. **176**(8): p. 1167-75.
5. Wennberg, J.E., et al., *Inpatient care intensity and patients' ratings of their hospital experiences.* Health Aff (Millwood), 2009. **28**(1): p. 103-12.
6. Blumenthal, D., et al., *Tailoring Complex-Care Management, Coordination, and Integration for High-Need, High-Cost Patients, 2016.*, in *Vital Directions for Health and Health Care Series.* , Discussion paper. National Academy of Medicine. Washington DC., Editor. 2016.
7. Anderson, G.F., et al., *Attributes common to programs that successfully treat high-need, high-cost individuals.* Am J Manag Care, 2015. **21**(11): p. e597-600.
8. Brown, R.S., et al., *Six features of Medicare coordinated care demonstration programs that cut hospital admissions of high-risk patients.* Health Aff (Millwood), 2012. **31**(6): p. 1156-66.
9. Powers, B.W. and S.K. Chaguturu, *ACOs and High-Cost Patients.* N Engl J Med, 2016. **374**(3): p. 203-5.
10. Liberati, A., et al., *The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration.* BMJ, 2009. **339**: p. b2700.
11. Moher, D., et al., *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.* BMJ, 2009. **339**: p. b2535.
12. World bank. [cited 2017; Available from: http://en.wikipedia.org/wiki/World_Bank_high-income_economy
13. Andersen, R.M., *Revisiting the behavioral model and access to medical care: does it matter?* J Health Soc Behav, 1995. **36**(1): p. 1-10.
14. Kominski, G.F., *Changing the U.S. Health Care System: Key Issues in Health Services Policy and Management*. 2013: Wiley.
15. Wodchis, W.P., P.C. Austin, and D.A. Henry, *A 3-year study of high-cost users of health care.* Cmaj, 2016. **188**(3): p. 182-8.
16. Bynum, J.P.W., et al., *High-Cost Dual Eligibles' Service Use Demonstrates The Need For Supportive And Palliative Models Of Care.* Health Aff (Millwood), 2017. **36**(7): p. 1309-1317.
17. Wammes, J.J.G., et al., *Characteristics and healthcare utilisation patterns of high-cost beneficiaries in the Netherlands: a cross-sectional claims database study.* BMJ Open, 2017. **7**(11): p. e017775.
18. de Oliveira, C., et al., *Patients With High Mental Health Costs Incur Over 30 Percent More Costs Than Other High-Cost Patients.* Health Aff (Millwood), 2016. **35**(1): p. 36-43.
19. Guilcher, S.J., et al., *Who Are the High-Cost Users? A Method for Person-Centred Attribution of Health Care Spending.* PLoS One, 2016. **11**(3): p. e0149179.
20. Alexandre, L.M., *High-cost patients in a fee-for-service medical plan. The case for earlier intervention.* Med Care, 1990. **28**(2): p. 112-23.
21. DeLia, D., *Mortality, Disenrollment, and Spending Persistence in Medicaid and CHIP.* Med Care, 2017. **55**(3): p. 220-228.
22. Fitzpatrick, T., et al., *Looking Beyond Income and Education: Socioeconomic Status Gradients Among Future High-Cost Users of Health Care.* Am J Prev Med, 2015. **49**(2): p. 161-71.
23. Ganguli, I., R. Thompson, and T.G. Ferris, *What can five high cost patients teach us about health care spending?* Journal of General Internal Medicine, 2016. **1)**: p. S469.

24. Rosella, L.C., et al., *High-cost health care users in Ontario, Canada: demographic, socio-economic, and health status characteristics.* BMC Health Serv Res, 2014. **14**: p. 532.
25. Joynt, K.E., et al., *Contribution of preventable acute care spending to total spending for high-cost Medicare patients.* JAMA, 2013. **309**(24): p. 2572-8.
26. Garfinkel, S.A., G.F. Riley, and V.G. Iannacchione, *High-cost users of medical care.* Health Care Financ Rev, 1988. **9**(4): p. 41-52.
27. Reschovsky, J.D., et al., *Following the money: factors associated with the cost of treating high-cost Medicare beneficiaries.* Health Serv Res, 2011. **46**(4): p. 997-1021.
28. Beaulieu, N.D., et al., *Concentration of high-cost patients in hospitals and markets.* Am J Manag Care, 2017. **23**(4): p. 233-238.
29. Graven, P.F., et al., *Preventable acute care spending for high-cost patients across payer types.* Journal of Health Care Finance, 2016. **42**(3).
30. Figueroa, J.F., et al., *Characteristics and spending patterns of high cost, non-elderly adults in Massachusetts.* Healthc (Amst), 2017.
31. Monheit, A.C., *Persistence in health expenditures in the short run: prevalence and consequences.* Med Care, 2003. **41**(7 Suppl): p. III53-III64.
32. Tamang, S., et al., *Predicting patient 'cost blooms' in Denmark: a longitudinal population-based study.* BMJ Open, 2017. **7**(1): p. e011580.
33. Lieberman, S.M., et al., *Reducing the growth of Medicare spending: geographic versus patient-based strategies.* Health Aff (Millwood), 2003. **Suppl Web Exclusives**: p. W3-603-13.
34. Ku, L.J., M.J. Chiou, and L.F. Liu, *Variations in the persistence of health expenditures and the implications for the design of capitation payments in Taiwan.* J Health Serv Res Policy, 2015. **20**(3): p. 146-53.
35. Pritchard, D., et al., *What Contributes Most to High Health Care Costs? Health Care Spending in High Resource Patients.* J Manag Care Spec Pharm, 2016. **22**(2): p. 102-9.
36. Wodchis, W.P., P.C. Austin, and D.A. Henry, *A 3-year study of high-cost users of health care.* Cmaj, 2016.
37. Guo, J.J., et al., *Characteristics and risk factors associated with high-cost medicaid recipients.* Manag Care Interface, 2004. **17**(10): p. 20-27.
38. Hwang, W., et al., *Persistent high utilization in a privately insured population.* Am J Manag Care, 2015. **21**(4): p. 309-16.
39. Rais, S., et al., *High-cost users of Ontario's healthcare services.* Healthc Policy, 2013. **9**(1): p. 44-51.
40. Figueroa, J.F., et al., *Concentration of Potentially Preventable Spending Among High-Cost Medicare Subpopulations: An Observational Study.* Ann Intern Med, 2017.
41. Vuik, S.I., E.K. Mayer, and A. Darzi, *Patient Segmentation Analysis Offers Significant Benefits For Integrated Care And Support.* Health Aff (Millwood), 2016. **35**(5): p. 769-75.
42. Hayes, S.L., et al., *High-Need, High-Cost Patients: Who Are They and How Do They Use Health Care? A Population-Based Comparison of Demographics, Health Care Use, and Expenditures.* Issue Brief (Commonw Fund), 2016. **26**: p. 1-14.
43. Heider, D., et al., *Health care costs in the elderly in Germany: an analysis applying Andersen's behavioral model of health care utilization.* BMC Health Serv Res, 2014. **14**: p. 71.
44. Wennberg, J.E., *Tracking Medicine:A Researcher's Quest to Understand Health Care: A Researcher's Quest to Understand Health Care*. 2010: Oxford University Press, USA.
45. Brinkman-Stoppelenburg, A., J.A. Rietjens, and A. van der Heide, *The effects of advance care planning on end-of-life care: a systematic review.* Palliat Med, 2014. **28**(8): p. 1000-25.
46. Dixon, J., T. Matosevic, and M. Knapp, *The economic evidence for advance care planning: Systematic review of evidence.* Palliat Med, 2015. **29**(10): p. 869-84.
47. Klingler, C., J. in der Schmitten, and G. Marckmann, *Does facilitated Advance Care Planning reduce the costs of care near the end of life? Systematic review and ethical considerations.* Palliat Med, 2016. **30**(5): p. 423-33.

48. World Health Organization, *Strengthening of palliative care as a component of integrated treatment throughout the life course.* Journal of pain & palliative care pharmacotherapy, 2014. **28**(2): p. 130-4.
49. Stadhouders, N., et al., *Policy options to contain healthcare costs: a review and classification.* Health Policy, 2016. **120**(5): p. 486-94.
50. Miller, D.C., et al., *Large variations in Medicare payments for surgery highlight savings potential from bundled payment programs.* Health Aff (Millwood), 2011. **30**(11): p. 2107-15.
51. Camacho, E.M., et al., *Long-term cost-effectiveness of collaborative care (vs usual care) for people with depression and comorbid diabetes or cardiovascular disease: a Markov model informed by the COINCIDE randomised controlled trial.* BMJ Open, 2016. **6**(10): p. e012514.
52. Druss, B.G. and E.R. Walker, *Mental disorders and medical comorbidity*, in *Research Synthesis Report 21*. 2011, Robert Wood Johnson Foundation: Princeton, NJ.
53. Bodenheimer, T., *Strategies to Reduce Costs and Improve Care for High-Utilizing Medicaid Patients: Reflections on Pioneering Programs*. 2013, Centre for Health Care Strategies.
54. Tricco, A.C., et al., *Effectiveness of quality improvement strategies for coordination of care to reduce use of health care services: a systematic review and meta-analysis.* CMAJ, 2014. **186**(15): p. E568-78.
55. Vrijhoef, B. and R. Thorlby, *Developing care for a changing population: supporting patients with costly, complex needs*. 2016, Nuffield Trust.
56. Aldridge, M.D. and A.S. Kelley, *The Myth Regarding the High Cost of End-of-Life Care.* American journal of public health, 2015. **105**(12): p. 2411-2415.
57. Buck, J.A., J.L. Teich, and K. Miller, *Use of mental health and substance abuse services among high-cost Medicaid enrollees.* Adm Policy Ment Health, 2003. **31**(1): p. 3-14.
58. Coughlin, T.A., T.A. Waidmann, and L. Phadera, *Among dual eligibles, identifying the highest-cost individuals could help in crafting more targeted and effective responses.* Health Aff (Millwood), 2012. **31**(5): p. 1083-91.
59. Coughlin, T.A. and S.K. Long, *Health care spending and service use among high-cost Medicaid beneficiaries, 2002-2004.* Inquiry, 2009. **46**(4): p. 405-17.
60. Hirth, R.A., et al., *New Evidence on the Persistence of Health Spending.* Medical Care Research and Review, 2015. **72**(3): p. 277-297.
61. Hunter, G., et al., *Health Care Utilization Patterns Among High-Cost VA Patients With Mental Health Conditions.* Psychiatr Serv, 2015. **66**(9): p. 952-8.
62. Reid, R., et al., *Conspicuous consumption: characterizing high users of physician services in one Canadian province.* J Health Serv Res Policy, 2003. **8**(4): p. 215-24.
63. Riley, G.F., *Long-term trends in the concentration of Medicare spending.* Health Aff (Millwood), 2007. **26**(3): p. 808-16.
64. Von Korff, M. and J. Marshall, *High cost HMO enrollees. Analysis of one physician's panel.* HMO Pract, 1992. **6**(1): p. 20-5.
65. Zulman, D.M., et al., *Multimorbidity and healthcare utilisation among high-cost patients in the US Veterans Affairs Health Care System.* BMJ Open, 2015. **5**(4): p. e007771.
66. Bayliss, E.A., et al., *Applying Sequential Analytic Methods to Self-Reported Information to Anticipate Care Needs.* EGEMS (Wash DC), 2016. **4**(1): p. 1258.
67. Boscardin, C.K., et al., *Predicting cost of care using self-reported health status data.* BMC health services research, 2015. **15**: p. 406.
68. Chang, H.Y., et al., *Identifying Consistent High-cost Users in a Health Plan: Comparison of Alternative Prediction Models.* Med Care, 2016. **54**(9): p. 852-9.
69. Hensel, J.M., et al., *Rates of Mental Illness and Addiction among High-Cost Users of Medical Services in Ontario.* Can J Psychiatry, 2016. **61**(6): p. 358-66.
70. Joynt, K.E., et al., *Segmenting high-cost Medicare patients into potentially actionable cohorts.* Healthc (Amst), 2017. **5**(1-2): p. 62-67.
71. Lee, D.C., et al., *Chronic conditions and medical expenditures among non-institutionalized adults in the United States.* International Journal for Equity in Health, 2014. **13 (1) (no pagination)**(105).
72. Leininger, L.J., et al., *Predicting high-need cases among new Medicaid enrollees.* The American journal of managed care, 2014. **20**(9): p. e399-e407.

73. Robst, J., *Developing Models to Predict Persistent High-Cost Cases in Florida Medicaid.* Popul Health Manag, 2015. **18**(6): p. 467-76.
74. Lauffenburger, J.C., et al., *Longitudinal Patterns of Spending Enhance the Ability to Predict Costly Patients: A Novel Approach to Identify Patients for Cost Containment.* Med Care, 2017. **55**(1): p. 64-73.
75. Ash, A.S., et al., *Finding future high-cost cases: comparing prior cost versus diagnosis-based methods.* Health Serv Res, 2001. **36**(6 Pt 2): p. 194-206.
76. Aldridge, M.D. and A.S. Kelley, *The Myth Regarding the High Cost of End-of-Life Care.* Am J Public Health, 2015. **105**(12): p. 2411-5.
77. Lee, N.S., et al., *High-Cost Patients: Hot-Spotters Don't Explain the Half of It.* J Gen Intern Med, 2017. **32**(1): p. 28-34.

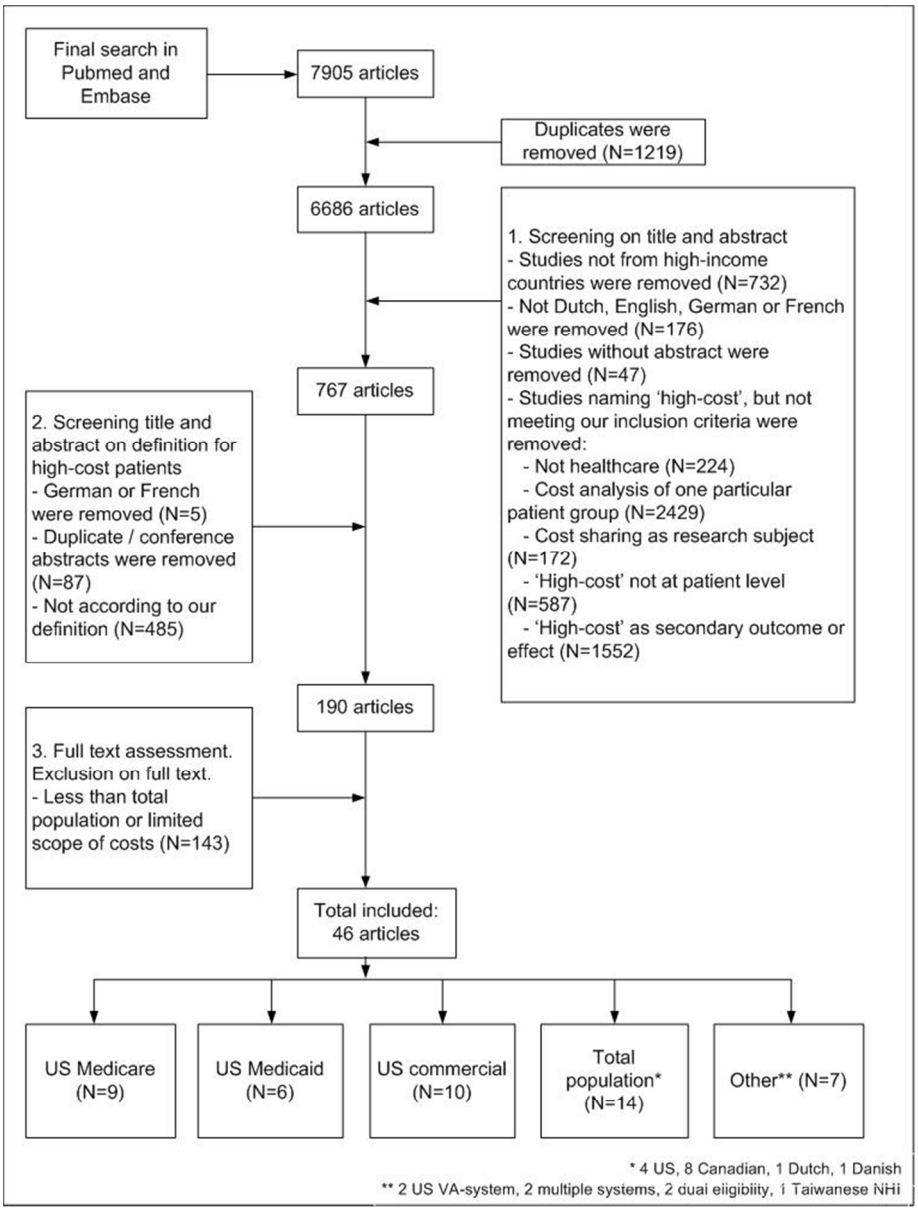


Figure 1. Selection process.

202x265mm (96 x 96 DPI)

Table 1. Description of the included studies.

Author(s), country	Methodological approach	Study period	Definition high-cost	Study population: in- and exclusion criteria	Cost data
Aldridge and Kelly[56], United States	Descriptive	2011	Top-5%	US population	Total spending was identified from a combination of data from MEPS, the Health and Retirement Study, peer reviewed literature, published reports, 2011 MEPS, 2011 National Health Expenditure Accounts.
Alexandre[20], United States	Descriptive, repeated measures	1981-1984	High-cost: >$5000 Very HC: >$25000	Personnel, spouse and children (<65 years) of one bank.	All expenses covered by The Plan.
Buck et al.[57], United States	Descriptive	1995	Top-10%	Medicaid population in 10 states. **Ex:** dually eligible, ≥65 years, enrolled in capitated plans, missing sex or birthdate.	Total Medicaid expenditures
Coughlin et al.[58], United States	Descriptive	2006-2007 (1 year)	Top-10%	Medicare beneficiaries and dual eligibles	Spending paid for by the public programs
Coughlin and Long [59], United States	Descriptive	2002-2004	Various. Top-1%, Top-5%, Top-10%, Top-25%, Top-50%	2002 national Medicaid population (living in institutions and community). **Ex:** who received only SCHIP coverage or never full benefits. Top-0.1% of spenders.	Medicaid
de Oliveira et al.[18], Canada	Descriptive	2012	Top-10%, top-5%, top-1%. Mental health HC patients: mental health >50% of total costs.	All adult patients (18 and older) who had at least 1 encounter with the Ontario health care system in 2012. **Ex:** all individuals who did not have a valid Ontario Health Insurance Plan number.	Most publicly funded healthcare services.
Garfinkel et al.[26], United States	Descriptive, logistic regression	1980	<65: top-10% >65: top-15%	Civilian population, not living in institutions. In some analysis, children < 17 were excluded.	Charges for all services (survey). Excluding: Ambulatory dentistry, nursing home care.
Guo et al.[37], United States	Descriptive, logistic regression	1999-2000	Top-10% of average monthly expenses	Medicaid, FFS recipients younger than 65. **Ex:** nursing home recipients	Medicaid costs
Hirth et al.[60], United States	Descriptive, logistic regression	2003-2008	High: top-10% Moderate: top-10%-30% Low: bottom-70% Usually low Low/moderate Sometimes high Often high Usually high	Under-65 population (Truven Health MarketScan database); enrollees and dependents of more than 100, mainly self-insured, medium and large employers Only people enrolled continuously are included. Attrition (a minority was enrolled each year) due to several reasons: death, retirement, children aging out of dependent status etc..	Data from all carve-outs (e.g., prescription drug, mental health), including claims for which the deductible is imposed. All spending was adjusted to 2008 dollars using the medical cost Consumer Price Index. **Ex**: Out-of-plan spending (e.g., OTC drugs, travel costs).
Hunter et al.[61], United States	Descriptive, linear regression	Fiscal year 2010	Top-5%	Cohort from Veterans Affairs administrative records, who were eligible for and received care in study period. **Ex**: individuals with schizophrenia, bipolar depression, other psychosis, alcohol dependence and abuse, drug dependence and abuse, PTSD, and/or depression.	Inpatient, outpatient, pharmacy, and non-VA contract care.
Hwang et al.[38], United	Descriptive, logistic regression	2008-2011	Top-10%	Employees from a large employer in Pennsylvenia and the employees' dependents. Only those continuously	Amount paid by the insurer and the amount of cost sharing paid by individuals.

States				enrolled.	
Joynt et al.[25], United States	Descriptive, linear regression	2009-2010	Top-10%	Medicare > 65 population. **Ex:** decedents, any Medicare advantage enrollment, not continuously enrolled.	In- and outpatient services.
Lieberman et al.[33], United States	Descriptive	1995-1999	Top-5%	Medicare FFS beneficiaries	Medicare spending
Monheit[31], United States	Descriptive, logistic regression	1996-1997	Various. Top-1%, Top-2%, Top-5%, Top-10%, Top-20%, Top-30%, Top-50%.	Representation of non-institutionalized civilian US population (survey respondents)	Total payments (including OOP, uncovered services, third party payments).
Rais et al.[39], Canada	Descriptive	2009-2010 (1 year)	Top-5%	Cost consuming users of hospital and home care services at the provincial level.	Hospital and home care services. Excluding: Primary care and long term care use.
Reid et al.[62], Canada	Descriptive	1996-1997 (1 year)	Top-5%	≥18 years and older enrolled in the province's universal health care plan	Medical services costs in a universal health care plan (physician and hospital services)
Reschovsky et al.[27], United States	Descriptive, logistic regression	2006, or 12 months before death	Top-25%	Medicare FFS beneficiaries, ≥1 CTS survey, With USOC physician. **Ex:** ESRD beneficiaries.	Standardized total costs of Medicare part A and B
Riley [63], United States	Descriptive	1975-2004	Top-1% Top-5%	Medicare, beneficiaries entitled to Part A and B	Medicare costs
Rosella et al.[24], Canada	Descriptive, multinomial logistic regression	2003-2008	Top-5% Top-1%, top-2%-5%, top-6-50%	Ontario residents. Participants of the CCH Survey. **Ex:** Institutionalized. Full-time members of the Canadian forces. Persons living in remote areas/ aboriginal reserves. Ages 12-18.	Those covered by Ontario's Universal Health Insurance Plan (OHIP). **Ex**: Some prescription drug costs, allied health services, dental care, eye care, assistive devices.
Von Korff and Marshall[64], United States	Descriptive	1989-1990 (1 year)	Top-15.1%	Enrollees of one primary care physician, enrolled at Group Health Cooperative.	Healthcare costs (visit registration, inpatient, pharmacy, laboratory, radiology). Excluding: Outside purchased service costs
Wodchis et al.[15], Canada	Descriptive	April 1, 2009 – March 31, 2012	Top-1% Top-5% Top-10% Top-50%	People with a recorded age of less than 105 years who were alive on Apr. 1 in any of the three study years and who had a valid Ontario health care at any time between Apr. 1 2009 and March 31 2012.	Costs refer to health care expenditures that have been allocated to patient encounters for health care. All medically necessary care, both acute and long term, as covered by public health insurance. **Ex**: Public health, community service agencies and many other programs, as well as for administrative (government) staff. Private home-care, privately insured medication costs.
Zulman et al.[65], United States	Descriptive, regression analyses	Fiscal year 2010	Top-5%	Veterans served by the VA System, who received inpatient or outpatient VA care.	Outpatient and inpatient, pharmacy, VA-sponsored contract care
Ku et al.[34], Taiwan	Descriptive, generalized estimating equations	2005-2009	Top-10%, top-11-25%	Survey respondents 65 years of age and older	National health insurance

Bayliss et al.[66], United States	Predictive modeling, cluster analysis	2014	Top-25%	Members with new Kaiser Permanente Colorado benefits and who completed the Brief Health Questionnaire	Per-member-per-month costs from Kaiser Permanente Colorado health system
Beaulieu et al.[28], United States	Descriptive, logistic regression	2011-2012	Top-10%	FFS Medicare population. Excluding patients <65 years, enrolled in Medicare advantage, and those not continuously enrolled in Parts A and B.	Standardized Medicare costs, excluding prescription drug charges.
Boscardin et al.[67], United States	Descriptive, logistic regression	2009	Top-10%	Employees enrolled in the Safeway health insurance program in 2009, with biometric and self-repored health status data (HRQ). **Ex**: dependents covered through a family member.	Safeway's health plan
Bynum et al.[16], United States	Descriptive, multinominal logistic regression	2010-2011	Top-10% in each state Persistently HC, died in 2011, or converted	Dually eligible adults with full Medicaid eligibility; in the 36 states that had usable and complete Medicaid data	Medicare and Medicaid
Chang et al.[68], United States	Descriptive, logistic regression	2007-2009	Consistent high-user: top-20% in four consecutive half year periods (≡ 6.14% of the population) Point high-user: top-6.14% in 1 year	Enrollees from 4 health plans who were 1) continuously enrolled 2) incurred ≥$100 each year 3) 4 largest plan 4) aged between 18 and 62 in 2007. **Ex:** those who died.	Commercial health plans
DeLia[21], United States	Descriptive, multinomial regression	2011-2014	Top-1%, top-2-10%, Persistently extreme: 4 years top-1% Persistently high: 4 years in top-10%	Medicaid/CHIP beneficiaries in New Jersey, newly covered individuals under the ACA (2014) were excluded, Medicaid/Medicare dual eligibles were excluded	Medicaid FFS claims and managed care encounters and CHIP
Figueroa et al.[30], United States	Descriptive, chi-square	2012	Top-10%	Adults 18-64 year without FFS Medicare coverage or Medicare Advantage coverage.	Massachusetts All-Payer Claims database; nearly a universal account of all health care delivered in the state with the exception of Medicare FFS.
Figueroa et al.[40], United States	Descriptive	2012	Top-10%	All Medicare patients, excluding those with Medicare Advantage coverage, who were not continually enrolled in part A and B	Standardized Medicare costs.
Ganguli et al.[23], United States	Descriptive, retrospective chart review, interview analysis	2005-2011	Five archetypal patients among the 50 costliest / 1500 highest cost patients	Patients selected by costs and a prospective risk score to participate in a Centers for Medicare and Medicaid care management project, >18 years and had sufficient cognitive capacity to participate in an interview, or if deceased had family members who were able to give sufficient information.	Total Medicare payments
Graven et al.[29], United States	Descriptive	2011-2013	Top-10%, Episodically high-cost, persistently high-cost	Adults ages 19 and over, enrolled in Oregon Medicaid, commercial or Medicare Advantage programs. Only those with continuous enrollment in 2011 and 2012 were included. **Ex:** dual eligibles, and individuals who had 'coordination of benefit'-claims or with negative total spending in any of the quarters.	Total Medicaid, commercial or Medicare Advantage payments (acute care expenditures), excluding spending on prescription drugs

Guilcher et al.[19], Canada	Descriptive	1 April 2010 – 31 March 2011	Top-5%	All persons eligible for provincial health insurance residing in the community, who had at least one interaction with the system in the last five years	All publicly funded healthcare in a universal public healthcare system
Hensel et al.[69], Canada	Descriptive, logistic regression	1 April 2011 – 31 March 2012	Top-1%, top-2-5%, top-6-50%, bottom-50%, and zero-cost referent group	All Ontario residents, with a valid Ontario health care, 18 years of age or older, and medical care costs greater than zero	Ontario health insurance plan, for all hospital and home care services, including physician care, costs related to outpatient physician services were not included
Joynt et al.[70], United States	Descriptive	2011 and 2012	Top-10%	All Medicare patients, excluding those with Medicare Advantage coverage, who were not continually enrolled in part A and B, or who died during the study period	Standardized Medicare costs.
Lee et al.[71], United States	Descriptive, cluster analysis	2012	Top-10%	Medicare patients hospitalized exclusively at Cleveland Clinic Health System and received at least 90% of their primary care services at a CCHS facility	CCHS facility costs, post-acute care services were only included for those patients who were admitted to a CCHS post-acute care facility.
Leininger et al.[72], United States	Descriptive, logistic regression	2009-2010 (one year)	Top-10%	New enrollees for Medicaid who completed a self-reported health needs assessment	Medicaid costs.
Pritchard et al.[35], United States	Descriptive	2011	Top-5%	Managed care population, of all ages, with at least 180 days continuous enrollment prior 1 January 2011, patients with gaps in enrollment greater than 30 days were excluded (so no uninsured or patients enrolled in tradiotional FFS Medicare or Medicaid programs)	Medical and pharmaceutical claims for more than 80 US health plans, the total amount reimbursed by the insurer plus the plan member's out-of-pocket share
Tamang et al.[32], Denmark	Descriptive, prediction modeling	2004-2011	Top-10%	Entire population of Western Denmark, with a full year of active residency in year 1	Danish National Health Service
Wammes et al.[17], Netherlands	Descriptive	2013	Top-1%, top-2-5%, bottom-95%	Beneficiaries of one Dutch health insurer	Dutch curative health system, basic benefit package including voluntary complementary insurance benefits.
Fitzpatrick et al.[22], Canada	Descriptive, logistic regression	2003/5 and five years follow up	Top-5%	Participants from two cycles of (CCHS) surveys, representative of the population ≥ 12 years and living in private dwellings. ≥ 18 years. **Ex:** baseline high-cost	Ontario health insurance plan
Robst[73], United States	Descriptive, logistic regression	2005-2010	Top-1% in some years, or in six years	Medicaid beneficiaries with fee-for-service coverage for at least 6 months in all 6 years	Medicaid
Lauffenburger et al.[74], United States	Descriptive, group-based trajectory modeling	2009-2011	Top-5%	Patients ≥18 years, with continuous eligibility for the entire calendar year, with ≥1 calendar year before their entry year and with ≥1 medical and pharmacy claim in both the baseline and entry year.	Medical and prescription data of Aetna, a large US nationwide insurer
Ash et al.[75], United States	Descriptive, logistic regression	1997-1998	Top-0.5% with highest predicted costs, top-0.5% prior cost.	Individuals eligible for at least one month in each of the two study years	MEDSTAT MarketScan Research Database, consisting of inpatient and outpatient care from individuals covered by employee-sponsored plans. Outpatient pharmacy costs were excluded.
Powers and Chaguturu[9], United States	Descriptive	2014	Top-1%	Patients of Partners HealthCare integrated delivery System	Medicare, Medicaid, commercial are compared

Table 2. Predisposing, enabling and need factors for high-cost patients.

Variables	Number of studies
Predisposing factors	
Age	27[17, 20-22, 24, 25, 27-31, 34, 35, 37, 57, 59, 60, 62-64, 66-69, 72, 74, 76]
Gender = male	10 [17, 18, 20, 21, 25-27, 37, 71, 73]
Gender = female	17 [17, 19-21, 24, 29, 30, 57, 59, 60, 64, 66, 67, 70]
Ethnicity = black /African American	4 [25, 27, 28, 63]
Ethnicity = white	5 [22, 24, 57, 59, 73]
Ethnicity = less likely black or Hispanic	3 [31, 59, 73]
Ethnicity = less likely immigrant	1 [22]
Ethnicity = less likely whites	1 [70]
Region	4 [25, 26, 59, 60]
Urban residence	6 [19, 25, 28, 34, 37, 70]
Rural residence	1 [60]
Living institutionalized	3 [21, 27, 58]
Employment status: part-time, unemployed, early retiree	2 [26, 60]
Job satisfaction	1 [67]
Marital status: divorced/widow/separated	1 [34]
Marital status: married	1 [26]
Receive care in many census divisions	1 [27]
Harmful habits	3 [24, 67, 72]
Union membership	1 [60]
Enabling factors	
Health insurance	
Medicare: more likely dual eligible	6 [25, 27, 28, 40, 63, 70]
Medicaid: specific eligibility status	4 [37, 57, 59, 73]
Commercial: increased insurance	2 [60, 66]
Total population: Medicaid eligibility	1 [26]
Total population: insurance status had no effect	1 [31]
Income	
Positive relation with high costs	3 [26, 31, 60]
Negative relation	4 [18, 22, 62, 69]
No relation	3 [24, 27, 34]
Organizational enabling factors	
Primary care physician supply	1 [25]
Specialist physician supply	1 [25]
Hospital bed supply	1 [25]
Medical specialist as usual source of care	1 [27]
Proportion of physicians who are medical specialists	2 [27, 28]
Inadequate time during office visits	1 [27]
Proportion of providers operating for profit	2 [27, 28]
Teaching hospitals	1 [28]
Low nurse-to-staffing ratios	1 [28]
Low supply of long term care beds	1 [28]
Physician-to-population ratio (negative relation)	1 [26]
Regular medical doctor or hospital	1 [72]
Regular medical doctor (negative relation)	1 [24]
Need factors	
A00–B99 Certain infectious and parasitic diseases	7 [15, 17, 21, 22, 60, 68, 73]
C00–D48 Neoplasms	18 [15, 17, 22, 25, 28, 29, 34, 35, 38, 39, 60-63, 65, 70, 74, 77]
D50–D89 Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	4 [16, 21, 35, 62]

E00–E90 Endocrine, nutritional and metabolic diseases	28 [16, 17, 21, 22, 25, 28-30, 32-34, 37, 38, 58, 59, 61-68, 70, 72, 74, 75, 77]
F00–F99 Mental and behavioral disorders	32 [9, 15-18, 21, 22, 24, 25, 28-30, 33, 37, 39, 57-65, 67-70, 72-74, 77]
G00–G99 Diseases of the nervous system	9 [17, 21, 32, 38, 39, 62, 68, 70, 73]
H00–H59 Diseases of the eye and adnexa	5 [17, 22, 37, 39, 62]
I00–I99 Diseases of the circulatory system	32 [9, 15-18, 21, 22, 25, 28-30, 32-35, 38, 39, 58, 60-68, 70, 72, 74, 75, 77]
J00–J99 Diseases of the respiratory system	26 [9, 15-17, 21, 22, 25, 28-30, 32, 34, 37-39, 59, 61-63, 66, 68, 70, 72, 74, 75, 77]
K00–K93 Diseases of the digestive system	9 [17, 18, 21, 22, 39, 60-62, 73]
L00–L99 Diseases of the skin and subcutaneous tissue	5 [17, 21, 22, 37, 62]
M00–M99 Diseases of the musculoskeletal system and connective tissue	16 [9, 21, 22, 28, 35, 60-62, 64, 65, 67, 68, 70, 74, 77]
N00–N99 Diseases of the genitourinary system	20 [9, 16, 17, 21, 22, 25, 28-30, 32, 34, 35, 38, 39, 60-63, 70, 77]
O00–O99 Pregnancy, childbirth and the puerperium	5 [15, 30, 37, 62, 64]
Q00–Q99 Congenital malformations, deformations and chromosomal abnormalities	1 [32]
R00–R99 Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	7 [17, 22, 37, 62, 64, 67, 77]
S00–T98 Injury, poisoning and certain other consequences of external causes	8 [15, 17, 22, 37, 39, 60, 70, 77]
Z00–Z99 Factors influencing health status and contact with health services	3 [17, 22, 39]
Chronic illness	22 [15, 17, 21, 24, 26, 28-30, 32-34, 37, 40, 61-66, 70, 74, 76]
Multimorbidity / burden of comorbid illness	24 [9, 17, 19, 21, 24-27, 29, 30, 35, 37, 38, 60-63, 65, 67, 70, 73-76]
Decedents / survival	15 [15-17, 19, 21, 26, 27, 31-33, 37, 62, 63, 70, 76]
Activities daily living	5 [26, 31, 34, 58, 66]
Health status	8 [24, 26, 31, 33, 34, 38, 64, 66]

Table 3. Expenditure patterns and utilization of high-cost patients.

Spending category	Number of studies
(Inpatient) hospital care	30 [15-20, 23, 24, 27-30, 32-35, 37-40, 58, 59, 61, 63-65, 67, 70, 72, 77]
Subacute care / postacute care services rehabilitation	10 [9, 15, 27, 30, 35, 39, 40, 58, 59, 70]
Hospitalizations/ admission / patient days/ length of stay	17 [17-20, 23, 25, 26, 30, 35, 37, 61, 62, 65, 67, 72, 74, 77]
Emergency department	12 [19, 25, 29, 35, 37-39, 61, 65, 67, 74, 77]
Outpatient (physician) visits	13 [19, 20, 27, 30, 34, 35, 37, 38, 61, 63, 65, 73, 74]
Long term care	9 [15, 16, 30, 40, 58, 59, 61, 71, 73]
Mental health	9 [17, 18, 37, 39, 57, 59, 61, 65, 73]
Physician services	12 [15, 18, 27, 35, 37, 38, 61-65, 73]
Intensive care unit	2 [17, 77]
Prescription drugs	14 [17, 19, 23, 30, 35, 37, 38, 59, 65, 68, 70, 72, 74, 77]
Persistency	
Subsequent use	14 [16, 20-23, 29, 31-33, 59, 60, 63, 68, 73]
Prior use	5 [20, 22, 32, 67, 75]
Persistent users	17 [16, 20-23, 25, 29, 31-33, 59, 60, 63, 67, 68, 73, 75]

Appendix 1. Final search strategy.

Pubmed:
(((((((High-cost*)) OR (high spending)) OR (Costliest)) OR (highest-cost*))) AND ((((((Patient*)) OR (Individual*)) OR (Benefici*)) OR (Person*)) OR (user*)) NOT medline[sb])) OR (((((("Economics, Hospital"[Mesh]) OR "Economics, Medical"[Mesh]) OR "Health Care Sector"[Mesh])) OR ("Costs and Cost Analysis"[Mesh]))) AND (((((((High-cost*)) OR (high spending)) OR (Costliest)) OR (highest-cost*))) AND ((((((Patient*)) OR (Individual*)) OR (Benefici*)) OR (Person*)) OR (user*))))

Embase:

1	(high-cost* or high spending or Costliest or highest-cost*).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
2	(patient* or individual* or benefici* or person* or user*).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
3	"hospital cost"/ or "health care cost"/ or "cost"/ or economic aspect/ or "hospital utilization"/ or medicare/ or exp medicaid/
4	1 and 2 and 3
5	((high-cost* or high spending or Costliest or highest-cost*) adj3 (patient* or individual* or benefici* or person* or user*)).mp.
6	4 or 5

Reporting checklist for systematic review and meta-analysis.

Based on the PRISMA guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the PRISMA reporting guidelines, and cite them as:

Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement

		Reporting Item	Page Number
	#1	Identify the report as a systematic review, meta-analysis, or both.	1
Structured summary	#2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number	2
Rationale	#3	Describe the rationale for the review in the context of what is already known.	4
Objectives	#4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
Protocol and registration	#5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address) and, if available, provide registration information including the registration number.	-

Eligibility criteria	#6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rational	5,6
Information sources	#7	Describe all information sources in the search (e.g., databases with dates of coverage, contact with study authors to identify additional studies) and date last searched.	5
Search	#8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5 (appendix)
Study selection	#9	State the process for selecting studies (i.e., for screening, for determining eligibility, for inclusion in the systematic review, and, if applicable, for inclusion in the meta-analysis).	5,6
Data collection process	#10	Describe the method of data extraction from reports (e.g., piloted forms, independently by two reviewers) and any processes for obtaining and confirming data from investigators.	6,7
Data items	#11	List and define all variables for which data were sought (e.g., PICOS, funding sources), and any assumptions and simplifications made.	6
Risk of bias in individual studies	#12	Describe methods used for assessing risk of bias in individual studies (including specification of whether this was done at the study or outcome level, or both), and how this information is to be used in any data synthesis.	-
Summary measures	#13	State the principal summary measures (e.g., risk ratio, difference in means).	6,7
Planned methods of analyis	#14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I2) for each meta-analysis.	7
Risk of bias across studies	#15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	-
Additional analyses	#16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	7

Study selection	#17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	8
Study characteristics	#18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citation.	8,9
Risk of bias within studies	#19	Present data on risk of bias of each study and, if available, any outcome-level assessment (see Item 12).	-
Results of individual studies	#20	For all outcomes considered (benefits and harms), present, for each study: (a) simple summary data for each intervention group and (b) effect estimates and confidence intervals, ideally with a forest plot.	8-15
Synthesis of results	#21	Present the main results of the review. If meta-analyses are done, include for each, confidence intervals and measures of consistency.	8-15
Risk of bias across studies	#22	Present results of any assessment of risk of bias across studies (see Item 15).	-
Additional analysis	#23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	8-15
Summary of Evidence	#24	Summarize the main findings, including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., health care providers, users, and policy makers	15
Limitations	#25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review level (e.g., incomplete retrieval of identified research, reporting bias).	15
Conclusions	#26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	18
Funding	#27	Describe sources of funding or other support (e.g., supply of data) for the systematic review; role of funders for the systematic review.	19

BMJ Open

A systematic review of high-cost patients' characteristics and healthcare utilization

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-023113.R1
Article Type:	Research
Date Submitted by the Author:	05-Jun-2018
Complete List of Authors:	Wammes, Joost Van der Wees, Philip; Radboud University Medical Centre, Nijmegen, IQ healthcare Tanke, Marit; IQ Healthcare / Celsus academy for sustainable healthcare Westert, Gert; Radboud university medical centre, Scientific Institute for Quality of Healthcare (IQ Healthcare Jeurissen, Patrick; Radboud Universiteit, IQ healthcare / Celsus academy for sustainable healthcare
Primary Subject Heading:	Health services research
Secondary Subject Heading:	Health policy
Keywords:	HEALTH SERVICES ADMINISTRATION & MANAGEMENT, high-need high-cost, integrated delivery of health care, health care utilization, health care costs

A systematic review of high-cost patients' characteristics and healthcare utilization

Joost Johan Godert Wammes[1], MSc
Radboud university medical center, Scientific Center for Quality of Healthcare / Celsus academy for sustainable healthcare. Nijmegen, the Netherlands.

Philip J van der Wees, PhD
Radboud university medical center, Scientific Center for Quality of Healthcare / Celsus academy for sustainable healthcare. Nijmegen, the Netherlands.
Philip.vanderwees@radboudumc.nl

Marit AC Tanke, MD, PhD
Radboud university medical center, Scientific Center for Quality of Healthcare / Celsus academy for sustainable healthcare. Nijmegen, the Netherlands. Marit.tanke@radboudumc.nl

Gert P Westert, PhD
Radboud university medical center, Scientific Center for Quality of Healthcare. Nijmegen, the Netherlands. Gert.westert@radboudumc.nl

Patrick PT Jeurissen, PhD
Radboud university medical center, Scientific Center for Quality of Healthcare / Celsus academy for sustainable healthcare. Nijmegen, the Netherlands.
Patrick.jeurissen@radboudumc.nl

1 Corresponding author:
Joost Wammes, MSc
Radboud university medical center, Scientific Center for Quality of Healthcare / Celsus academy for sustainable healthcare.
Address: P.O. Box 9101, 6500 HB Nijmegen, the Netherlands.
Phone: +31-24-361 6359,
Fax: +31-24-354 0166
Email: joost.wammes@radboudumc.nl

Article summary section

Abstract

Objectives: To investigate the characteristics and healthcare utilization of high-cost patients, and to compare high-cost patients across payers and countries.

Design: Systematic review.

Data sources: Pubmed and Embase databases were searched until October 30th, 2017.

Eligibility criteria and outcomes: Our final search was built on three themes: 'high-cost', 'patients', and 'cost' and 'cost analysis'. We included articles that reported characteristics and utilization of the top-X% (e.g. top-5%, top-10%) patients of costs of a given population. Analyses were limited to studies that covered a broad range of services, across the continuum of care. Andersen's behavioral model was used to categorize characteristics and determinants into predisposing, enabling and need characteristics.

Results: The studies pointed to a high prevalence of multiple (chronic) conditions to explain high-cost patients' utilization. Besides, we found a high prevalence of mental illness across all studies; and a prevalence higher than 30% in US Medicaid and total population studies. Furthermore, we found that high costs were associated with increasing age, but that still more than halve of high-cost patients were younger than 65. High costs were associated with higher incomes in the US, but with lower incomes elsewhere. Preventable spending was estimated at maximally ten percent of spending. The top-10%, top-5% and top-1% high-cost patients accounted for respectively 68%, 55%, and 24% of costs within a given year. Spending persistency varied between 24% and 48%. Finally, we found that no more than 30% of high-cost patients are in their last year of life.

Conclusions: High-cost patients make up the sickest and most complex populations and their high utilization is primarily explained by high levels of chronic and mental illness. High-cost

patients are diverse populations and vary across payer types and countries. Tailored interventions are needed to meet the needs of high-cost patients, and to avoid waste of scarce resources.

Key words: health services administration and medicine; high-need high-cost; integrated delivery of health care; health care utilization, health care costs

Strengths and limitations of this study

- Based on an extensive literature search, this review included 55 studies of high-cost patients' characteristics and healthcare utilization.
- Andersen's behavioural model was used to categorize the characteristics of high-cost patients into predisposing, enabling and need characteristics.
- Grey literature was not included in our systematic review. However, we identified 55 studies and compared high-cost patients' characteristics and healthcare utilization across payers and countries.
- We did not assess the quality of the studies because of the methodological diversity of the studies.

Background

It is widely known that healthcare costs are concentrated among a small group of 'high-cost' patients[1]. Although they receive substantial care from multiple sources, critical health care needs are unmet, and many receive unnecessary and ineffective care[2-5]. This suggests that high-cost patients are a logical group to seek for quality improvement and cost reduction.

Especially in the US, many providers or insurance plans have pursued this logic and developed programs for "high-need, high-cost patients". So far, such programs, including for example care coordination and disease management, have had favorable results in quality of care and health outcomes, and mixed results in their ability to reduce hospital use and costs[6]. Research has shown that the effectiveness and efficiency of the programs increase when interventions are targeted to the patients that most likely benefit[2, 7, 8]. Little is known however, about variations in clinical characteristics and care-utilization patterns across payer-defined groups or countries[9]. Such insight in the health requirements of high-cost patients is prerequisite for designing effective policy or program responses.

We conducted this systematic review to synthesize the literature on high-cost patients' characteristics and healthcare utilization. Andersen's behavioral model (see method section) was used to organize the findings. Our analysis was aimed at identifying drivers of costs that matter across payer types and countries. We aimed to inform the development of new interventions and policy, as well as future research in high-cost patients.

Methods

Our methodology was based on established guidance for conducting systematic reviews[10, 11]. Our main research questions was 'Who are the most expensive patients, what health care services do they use, what drives these high costs, and what drivers matter across payers and countries?'.

Study selection

A preliminary search in Pubmed was conducted to identify key articles and keywords. On the basis of these findings, we developed a search strategy covering the most important terms. We then reshaped the search strategy by consulting an information specialist of our university. The final search was built on three themes: 'high-cost', 'patients', and 'cost' and 'cost analysis'. The sensitivity of the search was verified with the key articles we found earlier. We searched Pubmed and Embase at October 30th, 2017. Full details of our search strategy are attached in appendix 1.

Inclusion and exclusion criteria

Articles were reviewed by Author A using title and abstract to identify potentially eligible studies. Author B verified a random sample of articles to guarantee specificity and sensitivity of the selection process. Only studies from high-income countries - as defined by the World Bank[12] – and studies published in 2000 and later were included. Studies not written in English and conference abstracts were excluded. In the second step, titles and abstracts were reviewed by Author A to assess whether articles fit within our definition of high-cost patients: the article reported characteristics and utilization of the top-X% (e.g. top-5%, top-10%) patients of costs of a given population. Author B verified a random sample of articles at this selection step. In the third step, full-text articles were retrieved and independently screened by

Author A and Author B for our inclusion criteria. At this step, we aimed for studies covering a broad range of services across the continuum of care at health system level, and excluded all studies with a narrow scope of costs (for example: hospital costs, pharmaceutical costs) and all studies with a narrow population base (primarily disease oriented studies, or studies in children). At each step of this selection process, (in-)consistencies were discussed until consensus was reached. On basis of the discussions, the criteria were refined and the prior selection process was repeated.

[Figure 1. Selection process.]

Data extraction

A data extraction form was developed by the research team to ensure the approach was consistent with the research question. Author A extracted all data. To guarantee specificity and sensitivity of data extraction, Author B and Author C both independently extracted the data of five random articles. A meeting was held to discuss (in-)consistencies in extraction results. On basis of this discussion, the data extraction form was refined and the prior data extraction was repeated. Per article the following key elements were extracted: author, year, country, definition of high-cost patients, in- and exclusion criteria of the study population, cost data used to determine total costs, characteristics of the high-cost patients such as diagnoses, age, gender, ethnicity, determinants for high costs including associated supply side factors (concerning the supply of health services), subpopulations, and health care use and costs (per subpopulation). We also made a narrative summary of the findings per article (provided in appendix 2). To identify the most important medical characteristics, only those diseases with a high prevalence (≥10%) among high-cost patient populations or medical characteristics overrepresented in high-cost populations were extracted. Medical

characteristics (prevalent diseases) were categorized and presented at the level of ICD10-chapters.

Data synthesis

Andersen's behavioral model was used to categorize characteristics and determinants for high costs into predisposing, enabling and need characteristics. Andersen's model assumes that healthcare use is a function of 1) characteristics that *predispose* people to use or not to use services, although such characteristics are not directly responsible for use (e.g. age, gender, education, ethnicity, beliefs) 2) *enabling* characteristics that facilitate or impede use of services (income/wealth/insurance as ability to pay for services, organization of service provision, health policy) 3) *needs* or conditions that laypeople or health care providers recognize as requiring medical treatment. The model also distinguishes between individual and contextual (measured at aggregate level, such as measures of community characteristics) determinants of service use. Andersen hypothesized that the variables would have differential ability to explain care use, depending on the type of service. For example, dental care (and other discretionary services) would be explained by predisposing and enabling characteristics, whereas hospital care would primarily be explained by needs and demographic characteristics[13, 14].

We presented all data according to five general categories, including study characteristics, predisposing characteristics, enabling characteristics, need characteristics, and expenditure categories and health care utilization. We presented summary tables of results, extracted central themes and topics from the studies, and summarized them narratively. All studies were analyzed according to payer and country to identify the most important drivers across settings.

Patient and Public Involvement

Patients and or public were not involved in the conduct of this study.

Results

General information

Our search strategy resulted in 7905 articles. After first broad eligibility assessment 767 articles remained. After screening of titles and abstracts, 190 articles remained for full-text screening, from which 55 were ultimately included (figure 1).

A description of the studies is given in table 1. The majority of the studies were conducted in the United States (N=42). The remaining studies were conducted in Canada (N=9), Germany (N=1), Denmark (N=1), the Netherlands (N=1), and Taiwan (N=1). All were retrospective cohort studies, and descriptive and logistic regression analysis were the main analytic approaches used. The study period ranged from six months to thirty years. The most frequent observation period was one year.

Table 1. Description of the included studies.

Author(s), country	Methodological approach	Study period	Definition high-cost	Study population: in- and exclusion criteria	Cost data
Aldridge and Kelly[15], United States	Descriptive	2011	Top-5%	US population	Total spending was identified from a combination of data from MEPS, the Health and Retirement Study, peer reviewed literature, published reports, 2011 MEPS, 2011 National Health Expenditure Accounts.
Ash et al.[16], United States	Descriptive, logistic regression	1997-1998	Top-0.5% with highest predicted costs, top-0.5% prior cost.	Individuals eligible for at least one month in each of the two study years	MEDSTAT MarketScan Research Database, consisting of inpatient and outpatient care from individuals covered by employee-sponsored plans. Outpatient pharmacy costs were excluded.
Bayliss et al.[17], United States	Predictive modeling, cluster analysis	2014	Top-25%	Members with new Kaiser Permanente Colorado benefits and who completed the Brief Health Questionnaire	Per-member-per-month costs from Kaiser Permanente Colorado health system
Beaulieu et al.[18], United States	Descriptive, logistic regression	2011-2012	Top-10%	FFS Medicare population. Excluding patients <65 years, enrolled in Medicare advantage, and those not continuously enrolled in Parts A and B.	Standardized Medicare costs, excluding prescription drug charges.
Boscardin et al.[19], United States	Descriptive, logistic regression	2009	Top-10%	Employees enrolled in the Safeway health insurance program in 2009, with biometric and self-repored health status data (HRQ). **Ex**: dependents covered through a family member.	Safeway's health plan
Buck et al.[20], United States	Descriptive	1995	Top-10%	Medicaid population in 10 states. **Ex:** dually eligible, ≥65 years, enrolled in capitated plans, missing sex or birthdate.	Total Medicaid expenditures
Bynum et al.[21], United States	Descriptive, multinominal logistic regression	2010-2011	Top-10% in each state Persistently HC, died in 2011, or converted	Dually eligible adults with full Medicaid eligibility; in the 36 states that had usable and complete Medicaid data	Medicare and Medicaid
Chang et al.[22], United States	Descriptive, logistic regression	2007-2009	Consistent high-user: top-20% in four consecutive half year periods (≡ 6.14% of the population) Point high-user: top-6.14% in 1 year	Enrollees from 4 health plans who were 1) continuously enrolled 2) incurred ≥$100 each year 3) 4 largest plan 4) aged between 18 and 62 in 2007. **Ex:** those who died.	Commercial health plans
Charlson et al. [23], United States	Quantile regression	2007 (six months)	Top-5%, top-10%	All enrollees of the MMC Plan who had an assigned primary care provider at Lincoln Medical and Mental Health Center.	Metroplus MMC costs, including inpatient, outpatient, ER, laboratory tests, and prescription drugs.
Charlson et al. [24], United States	Quantile regression	2009-2010	Top-5%, top-10%	Union of health and hospital workers in the Northeast, those who were consistently eligible for benefits over at least 22 months in 2009 and 2010 (self-insured trust fund), who also received DCG codes.	Inpatient, outpatient, emergency room, laboratory tests, behavioral health and prescription drugs.
Chechulin et al.	Logistic regression	2007/08-	Top-5%	All Ontario residents serviced by the Ontario healthcare	Total health system costs (including LTC), excluding

[25], Canada		2010/11		system during the fiscal year 2009/10. Patients under five, or who died during this year were excluded	outpatient oncology, outpatient dialysis, and outpatient clinic.
Cohen et al. [26], United States	Logistic regression	1996-2002	Top-10%,	Nationally representative sample of the Medical Expenditure Panel Survey	All direct payments to providers by individuals, private insurance, Medicare, Medicaid, and other payment sources for: inpatient and outpatient care; emergency room services, office-based medical provider services, home healthcare, prescription medicines, and other medical services and equipment.
Coughlin et al.[27], United States	Descriptive	2006-2007 (1 year)	Top-10%	Medicare beneficiaries and dual eligibles	Spending paid for by the public programs
Coughlin and Long [28], United States	Descriptive	2002-2004	Various. Top-1%, Top-5%, Top-10%, Top-25%, Top-50%	2002 national Medicaid population (living in institutions and community). **Ex:** who received only SCHIP coverage or never full benefits. Top-0.1% of spenders.	Medicaid
Crawford et al. [29], United States	Neural network modeling	1999-2001	Top-15%	Members of a health plan, where American Healthways, inc. provided disease management services. Only members with 24 months continuous enrollment were included.	Health plan costs.
DeLia[30], United States	Descriptive, multinomial regression	2011-2014	Top-1%, top-2-10%, Persistently extreme: 4 years top-1% Persistently high: 4 years in top-10%	Medicaid/CHIP beneficiaries in New Jersey, newly covered individuals under the ACA (2014) were excluded, Medicaid/Medicare dual eligibles were excluded	Medicaid FFS claims and managed care encounters and CHIP
de Oliveira et al.[31], Canada	Descriptive	2012	Top-10%, top-5%, top-1%. Mental health HC patients: mental health >50% of total costs.	All adult patients (18 and older) who had at least 1 encounter with the Ontario health care system in 2012. **Ex:** all individuals who did not have a valid Ontario Health Insurance Plan number.	Most publicly funded healthcare services.
Figueroa et al.[32], United States	Descriptive, chi-square	2012	Top-10%	Adults 18-64 year without FFS Medicare coverage or Medicare Advantage coverage.	Massachusetts All-Payer Claims database; nearly a universal account of all health care delivered in the state with the exception of Medicare FFS.
Figueroa et al.[33], United States	Descriptive	2012	Top-10%	All Medicare patients, excluding those with Medicare Advantage coverage, who were not continually enrolled in part A and B	Standardized Medicare costs.
Fitzpatrick et al.[34], Canada	Descriptive, logistic regression	2003/5 and five years follow up	Top-5%	Participants from two cycles of (CCHS) surveys, representative of the population ≥ 12 years and living in private dwellings. ≥ 18 years. **Ex:** baseline high-cost	Ontario health insurance plan
Fleishmann[35], United States	Logistic regression	1996-2003	Top-10%, top-5%	Nationally representative sample of the Medical Expenditure Panel Survey	All direct payments to providers by individuals, private insurance, Medicare, Medicaid, and other payment sources for: inpatient and outpatient care; emergency room services, office-based medical provider services, home healthcare, prescription medicines, and other medical services and equipment.

Ganguli et al.[36], United States	Descriptive, retrospective chart review, interview analysis	2005-2011	Five archetypal patients among the 50 costliest / 1500 highest cost patients	Patients selected by costs and a prospective risk score to participate in a Centers for Medicare and Medicaid care management project, >18 years and had sufficient cognitive capacity to participate in an interview, or if deceased had family members who were able to give sufficient information.	Total Medicare payments
Graven et al.[37], United States	Descriptive	2011-2013	Top-10%, Episodically high-cost, persistently high-cost	Adults ages 19 and over, enrolled in Oregon Medicaid, commercial or Medicare Advantage programs. Only those with continuous enrollment in 2011 and 2012 were included. **Ex:** dual eligibles, and individuals who had 'coordination of benefit'-claims or with negative total spending in any of the quarters.	Total Medicaid, commercial or Medicare Advantage payments (acute care expenditures), excluding spending on prescription drugs
Guilcher et al.[38], Canada	Descriptive	1 April 2010 – 31 March 2011	Top-5%	All persons eligible for provincial health insurance residing in the community, who had at least one interaction with the system in the last five years	All publicly funded healthcare in a universal public healthcare system
Guo et al.[39], United States	Descriptive, logistic regression	1999-2000	Top-10% of average monthly expenses	Medicaid, FFS recipients younger than 65. **Ex:** nursing home recipients	Medicaid costs
Hartmann et al. [40], Germany	Logistic regression	2010-2011	Top-10%	Enrollees 18 years and older of AOK Lower Saxony, Germany's 10th-largest statutory health insurer	In- and outpatient care, sickness benefits, rehabilitation, home nursing, ambulatory drug supply, prescribed therapeutic appliances and remedies.
Hensel et al.[41], Canada	Descriptive, logistic regression	1 April 2011 – 31 March 2012	Top-1%, top-2-5%, top-6-50%, bottom-50%, and zero-cost referent group	All Ontario residents, with a valid Ontario health care, 18 years of age or older, and medical care costs greater than zero	Ontario health insurance plan, for all hospital and home care services, including physician care, costs related to outpatient physician services were not included
Hirth et al.[42], United States	Descriptive, logistic regression	2003-2008	High: top-10% Moderate: top-10%-30% Low: bottom-70% Usually low Low/moderate Sometimes high Often high Usually high	Under-65 population (Truven Health MarketScan database); enrollees and dependents of more than 100, mainly self-insured, medium and large employers Only people enrolled continuously are included. Attrition (a minority was enrolled each year) due to several reasons: death, retirement, children aging out of dependent status etc..	Data from all carve-outs (e.g., prescription drug, mental health), including claims for which the deductible is imposed. All spending was adjusted to 2008 dollars using the medical cost Consumer Price Index. **Ex**: Out-of-plan spending (e.g., OTC drugs, travel costs).
Hunter et al.[43], United States	Descriptive, linear regression	Fiscal year 2010	Top-5%	Cohort from Veterans Affairs administrative records, who were eligible for and received care in study period. **Ex**: individuals with schizophrenia, bipolar depression, other psychosis, alcohol dependence and abuse, drug dependence and abuse, PTSD, and/or depression.	Inpatient, outpatient, pharmacy, and non-VA contract care.
Hwang et al.[44], United States	Descriptive, logistic regression	2008-2011	Top-10%	Employees from a large employer in Pennsylvenia and the employees' dependents. Only those continuously enrolled.	Amount paid by the insurer and the amount of cost sharing paid by individuals.
Izad Shenas[45], United States	Data mining techniques / predictive modeling	2006-2008	Top-5%, top-10%, top-20%	Nationally representative sample of the Medical Expenditure Panel Survey, household individuals ≥ 17 years (redundant records, or with zero personal-level weights were removed).	All direct payments to providers by individuals, private insurance, Medicare, Medicaid, and other payment sources for: inpatient and outpatient care; emergency room services, office-based medical provider services,

					home healthcare, prescription medicines, and other medical services and equipment.
Joynt et al.[46], United States	Descriptive	2011 and 2012	Top-10%	All Medicare patients, excluding those with Medicare Advantage coverage, who were not continually enrolled in part A and B, or who died during the study period	Standardized Medicare costs.
Joynt et al.[47], United States	Descriptive, linear regression	2009-2010	Top-10%	Medicare > 65 population. **Ex:** decedents, any Medicare advantage enrollment, not continuously enrolled.	In- and outpatient services.
Krause et al. [48], United States	Logistic regression	2009-2011	Top-5%, top-1%, >$100,000	Enrollees of Blue Cross Blue Shield of Texas, only members 18-63, with a zip code in Texas and continuous enrollment in 2009 were included.	Total claims expense, including expenditures for hospital care, outpatient facility services, and professional services.
Ku et al.[49], Taiwan	Descriptive, generalized estimating equations	2005-2009	Top-10%, top-11-25%	Survey respondents 65 years of age and older	National health insurance
Lauffenburger et al.[50], United States	Descriptive, group-based trajectory modeling	2009-2011	Top-5%	Patients ≥18 years, with continuous eligibility for the entire calendar year, with ≥1 calendar year before their entry year and with ≥1 medical and pharmacy claim in both the baseline and entry year.	Medical and prescription data of Aetna, a large US nationwide insurer
Lee et al., [51]United States	Descriptive, cluster analysis	2012	Top-10%	Medicare patients hospitalized exclusively at Cleveland Clinic Health System and received at least 90% of their primary care services at a CCHS facility	CCHS facility costs, post-acute care services were only included for those patients who were admitted to a CCHS post-acute care facility.
Leininger et al.[52], United States	Descriptive, logistic regression	2009-2010 (one year)	Top-10%	New enrollees for Medicaid who completed a self-reported health needs assessment	Medicaid costs.
Lieberman et al.[53], United States	Descriptive	1995-1999	Top-5%	Medicare FFS beneficiaries	Medicare spending
Meenan et al.[54], United States	Risk modeling.	1995-1996	Top-0.5%, top-1%	Enrollees of six HMOs, eligible for some period in 1995 and 1996, and who had an outpatient pharmacy benefit. Medicare Cost enrollees were excluded.	Total claims, including inpatient, outpatient, radiology, pharmacy, durable medical equipment, long-term care, laboratory.
Monheit [55], United States	Descriptive, logistic regression	1996-1997	Various. Top-1%, Top-2%, Top-5%, Top-10%, Top-20%, Top-30%, Top-50%.	Representation of non-institutionalized civilian US population (survey respondents)	Total payments (including OOP, uncovered services, third party payments).
Powers and Chaguturu[9], United States	Descriptive	2014	Top-1%	Patients of Partners HealthCare integrated delivery System	Medicare, Medicaid, commercial are compared
Pritchard et al.[56], United States	Descriptive	2011	Top-5%	Managed care population, of all ages, with at least 180 days continuous enrollment prior 1 January 2011, patients with gaps in enrollment greater than 30 days were excluded (so no uninsured or patients enrolled in traditional FFS Medicare or Medicaid programs)	Medical and pharmaceutical claims for more than 80 US health plans, the total amount reimbursed by the insurer plus the plan member's out-of-pocket share

Rais et al.[57], Canada	Descriptive	2009-2010 (1 year)	Top-5%	Cost consuming users of hospital and home care services at the provincial level.	Hospital and home care services. Excluding: Primary care and long term care use.
Reid et al.[58], Canada	Descriptive	1996-1997 (1 year)	Top-5%	≥18 years and older enrolled in the province's universal health care plan	Medical services costs in a universal health care plan (physician and hospital services)
Reschovsky et al.[59], United States	Descriptive, logistic regression	2006, or 12 months before death	Top-25%	Medicare FFS beneficiaries, ≥1 CTS survey, With USOC physician. **Ex:** ESRD beneficiaries.	Standardized total costs of Medicare part A and B
Riley [60], United States	Descriptive	1975-2004	Top-1% Top-5%	Medicare, beneficiaries entitled to Part A and B	Medicare costs
Robst[61], United States	Descriptive, logistic regression	2005-2010	Top-1% in some years, or in six years	Medicaid beneficiaries with fee-for-service coverage for at least 6 months in all 6 years	Medicaid
Rosella et al.[62], Canada	Descriptive, multinomial logistic regression	2003-2008	Top-5% Top-1%, top-2%-5%, top-6-50%	Ontario residents. Participants of the CCH Survey. **Ex:** Institutionalized. Full-time members of the Canadian forces. Persons living in remote areas/ aboriginal reserves. Ages 12-18.	Those covered by Ontario's Universal Health Insurance Plan (OHIP). **Ex**: Some prescription drug costs, allied health services, dental care, eye care, assistive devices.
Snider et al.[63], United States	Logistic regression	2004-2009	Top-20%	Employees from large US employers, from the Thomson Reuters Marketscan Commercial Claims and Encounters database with both BMI and claims in any given year. Pregnant women and underweight employees were excluded.	All inpatient, outpatient, and prescription claims.
Tamang et al.[64], Denmark	Descriptive, prediction modeling	2004-2011	Top-10%	Entire population of Western Denmark, with a full year of active residency in year 1	Danish National Health Service
Wammes et al.[65], Netherlands	Descriptive	2013	Top-1%, top-2-5%, bottom-95%	Beneficiaries of one Dutch health insurer	Dutch curative health system, basic benefit package including voluntary complementary insurance benefits.
Wodchis et al.[66], Canada	Descriptive	April 1, 2009 – March 31, 2012	Top-1% Top-5% Top-10% Top-50%	People with a recorded age of less than 105 years who were alive on Apr. 1 in any of the three study years and who had a valid Ontario health care at any time between Apr. 1 2009 and March 31 2012.	Costs refer to health care expenditures that have been allocated to patient encounters for health care. All medically necessary care, both acute and long term, as covered by public health insurance. **Ex**: Public health, community service agencies and many other programs, as well as for administrative (government) staff. Private home-care, privately insured medication costs.
Zhao et al.[67], United States	Descriptive, linear regression	1997-1999	Top-0.5%	Private insured, whose claims were covered in the Medstat MarketScan Research Database; a multi-source private sector healthcare database. All cases with a pharmacy benefit and at least one month of eligibility in each of the first two study years, or the last two study years.	Total medical costs, including inpatient plus ambulatory plus pharmacy costs, and deductibles, coinsurance and coordination-of-benefit payments.
Zulman et al.[68], United States	Descriptive, regression analyses	Fiscal year 2010	Top-5%	Veterans served by the VA System, who received inpatient or outpatient VA care.	Outpatient and inpatient, pharmacy, VA-sponsored contract care

A range of definitions for high-cost patients were used, and some studies used more than one definition to distinguish between age groups, between high- and very high-cost patients, or to study persistently high-cost patients (>1 year high costs). In general, patients belonging to the top-1%, top-5%, top-10%, or top-20% of spending were considered high-cost patients.

The study population differed between the studies. We categorized eighteen studies as 'total population' studies, including studies in universal insurance schemes (of all ages; nine Canadian studies, one Dutch, one German, and one Danish study), studies that combined data of different payers, or survey studies. Respectively nine, seven and fourteen studies were among US Medicare, US Medicaid or US commercial populations. The remaining studies compared high-cost patients in multiple US payers, or were among US dual eligibles (eligible for both Medicare and Medicaid), US Veterans Affairs (VA)-beneficiaries, or among elderly in the Taiwanese insurance system. Some studies used additional criteria to determine the population. Age, healthcare use, or insurance were most frequently used as secondary condition to determine the population.

In fifty studies, total costs per patient were based on the insurance plan or public program. In the remaining studies, total costs were based on a survey or identified from a variety of sources.

Predisposing characteristics

Table 2 presents predisposing, enabling and need characteristics associated with high-cost patients. Age was related to high-cost patients in several ways. First, high-cost patients were generally older, and higher age was associated with high costs. This held for each payer type. Second, persistently high-cost patients were generally older than episodic high-cost patients, and higher ages were associated with persistently high costs. Third, the magnitude of cost

concentration, and the threshold for high costs differed between age groups[66]. As younger groups are generally healthier, costs are concentrated among fewer individuals. Fourth, clinical diagnoses and utilization patterns varied across age groups[21, 65, 66], and some subgroups were related to particular ages, including mental health high-cost patients among younger ages[31]. Finally, although age was related to high costs, total population studies showed that approximately half of the high-cost populations were younger than 65[38, 65].

Table 2. Predisposing, enabling and need factors for high-cost patients.

Variables	Number of studies
Predisposing factors	
Age	32 [15, 17-20, 22, 25, 26, 28-30, 32, 34, 35, 37, 39-42, 47-50, 52, 55, 56, 58-60, 62, 63, 65]
Gender = male	9 [25, 30, 31, 39, 47, 51, 59, 61, 65]
Gender = female	16 [17, 19, 20, 26, 28, 30, 32, 37, 38, 42, 46, 55, 58, 62, 63, 65]
Ethnicity = black /African American	4 [18, 47, 59, 60]
Ethnicity = white	5 [20, 28, 34, 61, 62]
Ethnicity = less likely black or Hispanic	3 [28, 55, 61]
Ethnicity = less likely immigrant	1 [34]
Ethnicity = less likely whites	2 [46, 48]
Region	4 [28, 42, 45, 47]
Urban residence	6 [18, 38, 39, 46, 47, 49]
Rural residence	2 [25, 42]
Living institutionalized	3 [27, 30, 59]
Employment status: early retiree	1 [42]
Job satisfaction	1 [19]
Marital status: divorced/widow/separated/living alone	2 [26, 49]
Dependents less likely to incur high costs	1 [40]
Receive care in many census divisions	1 [59]
Harmful habits	3 [19, 52, 62]
Union membership	1 [42]
Education: less than a high-school degree (neigboorhod level)	1 [48]
Enabling factors	
Health insurance	
Medicare: more likely dual eligible	6 [18, 33, 46, 47, 59, 60]
Medicaid: specific eligibility status	4 [20, 28, 39, 61]
Commercial: increased insurance	2 [17, 42]
Total population: insurance status had no effect	1 [55]
Type of insurance	1 [40]
Income	
Positive relation with high costs	3 [26, 42, 55]
Negative relation	5 [25, 31, 34, 41, 58]

No relation	3 [49, 59, 62]
Organizational enabling factors	
Primary care physician supply	1 [47]
Specialist physician supply	1 [47]
Hospital bed supply	1 [47]
Medical specialist as usual source of care	1 [59]
Proportion of physicians who are medical specialists	2 [18, 59]
Inadequate time during office visits	1 [59]
Proportion of providers operating for profit	2 [18, 59]
Teaching hospitals	1 [18]
Low nurse-to-staffing ratios	1 [18]
Low supply of long term care beds	1 [18]
Regular medical doctor or hospital	1 [52]
Regular medical doctor (negative relation)	1 [62]
Need factors	
A00–B99 Certain infectious and parasitic diseases	9 [22, 26, 30, 34, 42, 61, 63, 65, 66]
C00–D48 Neoplasms	21 [18, 25, 34, 37, 42-44, 46-51, 56-58, 60, 63, 65, 66, 68]
D50–D89 Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	4 [21, 30, 56, 58]
E00–E90 Endocrine, nutritional and metabolic diseases	32 [16-19, 21, 22, 25, 27-30, 32, 34, 37, 39, 40, 43, 44, 46, 47, 49-53, 58, 60, 63-65, 67, 68]
F00–F99 Mental and behavioral disorders	34 [9, 18-23, 25, 27, 28, 30, 31, 33, 34, 37, 39-43, 46, 47, 50-53, 57, 58, 60-62, 65, 66, 68]
G00–G99 Diseases of the nervous system	10 [22, 30, 44, 46, 57, 58, 61, 63-65]
H00–H59 Diseases of the eye and adnexa	5 [34, 39, 57, 58, 65]
I00–I99 Diseases of the circulatory system	36 [9, 16-19, 21, 22, 25, 27, 29-31, 33, 34, 37, 40, 42-44, 46-53, 56-58, 60, 64-68]
J00–J99 Diseases of the respiratory system	30 [9, 16-18, 21, 22, 25, 26, 28, 30, 32, 34, 37, 39, 40, 43, 44, 46, 47, 49-52, 57, 58, 60, 64-67]
K00–K93 Diseases of the digestive system	9 [30, 31, 34, 42, 43, 57, 58, 61, 65]
L00–L99 Diseases of the skin and subcutaneous tissue	5 [30, 34, 39, 58, 65]
M00–M99 Diseases of the musculoskeletal system and connective tissue	15 [9, 18, 19, 22, 30, 34, 42, 43, 46, 50, 51, 56, 58, 65, 68]
N00–N99 Diseases of the genitourinary system	22 [9, 18, 21, 25, 30, 32, 34, 37, 40, 42-44, 46, 47, 49, 51, 56-58, 60, 64, 65]
O00–O99 Pregnancy, childbirth and the puerperium	5 [23, 33, 39, 58, 66]
Q00–Q99 Congenital malformations, deformations and chromosomal abnormalities	1 [64]
R00–R99 Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	6 [19, 34, 39, 51, 58, 65]
S00–T98 Injury, poisoning and certain other consequences of external causes	9 [34, 39, 42, 46, 48, 51, 57, 65, 66]
Z00–Z99 Factors influencing health status and contact with health services	3 [34, 57, 65]
Chronic illness	22 [15, 17, 18, 30, 32, 33, 35, 37, 39, 40,

	43, 46, 49, 50, 53, 58, 60, 62, 64-66, 68]
Multimorbidity / burden of comorbid illness	31 [9, 15, 16, 19, 23, 24, 29, 30, 33, 35, 37-40, 42, 43, 45-47, 50, 56, 58-63, 65, 67, 68]
Decedents / survival	14 [15, 21, 30, 38, 39, 46, 53, 55, 58-60, 64-66]
Activities daily living	7 [17, 26, 27, 35, 45, 49, 55]
Health status	9 [17, 26, 35, 44, 45, 49, 53, 55, 62]

Studies showed inconsistent results for gender. Respectively 9 and 16 studies noted males and females were overrepresented in high-cost patients. Besides, gender was associated with different segments of the high-cost population, including males in top-1% or persistently extreme-cost patients, and females in top-2-5% or persistently high-cost patients[30, 65], or males in mental health high-cost patients[31].

Eleven studies reported the association between ethnicity and high costs. In two Canadian total population studies and three US Medicaid studies whites were overrepresented among high-cost populations, whereas in four US Medicare studies Blacks were overrepresented.

Socioeconomic status is regarded as both a predisposing characteristic and an enabling characteristic in Andersen's model, and we found evidence for both relationships. One Canadian study found that high costs were most strongly associated with food insecurity, lower personal income, non-homeownership and living in highly deprived or low ethnic concentration neighborhoods[34]. Other studies found that social deprivation seemed to increase risk for high costs more than material deprivation[25].

Ganguli et al studied health beliefs among high-cost US Medicare patients: socioeconomic status, social network, patient activation, and relationships with and trust in the clinician and the health system all increased or decreased costs, depending on the context. Trust was particularly important, and modified the interaction between patient activation and costs: when patients trusted their physicians, patient activation was associated with lower costs. When trust was lacking, patient activation was associated with higher costs[36].

Health behaviors, including underweight, obesity, physical inactivity and former smoking were significantly related to high costs[62, 63].

Enabling characteristics

The studies' abilities to assess the effect of insurance were limited because most study populations were determined by insurance. Nevertheless, the studies indicated that increased insurance may have indicated specific or additional care needs. For example, six US Medicare studies reported that high-cost patients were more likely dually eligible and four US Medicaid studies reported that certain eligibility statuses were associated with high costs. In addition, increased insurance was associated with high costs because it lowers costs. Two US commercial studies mentioned that high-cost patients were more likely to have a health maintenance organization plan, a preferred provider organization plan, or comprehensive insurance compared to high-deductible health plans; and insured status was associated with less consideration of costs in decision making[36].

Twelve studies addressed the relationship between income and high costs. In three US studies higher incomes were associated with high costs, whereas five Canadian studies found that lower incomes were associated with (mental health) high costs. However, one US, one Taiwanese, and one Canadian study reported that income was not significantly related to high costs. Finally, among high-cost US Medicare patients, personal resources and education were associated with increased use of resources (higher SES was linked to higher priced care), but also with lower resources use[36].

Organizational enabling factors

The number of primary care physicians, specialists and hospital beds were associated with higher per capita preventable costs among high-cost US Medicare patients[47]. Reschovsky et

al found several weak or insignificant relationships between organizational factors and high costs within the high-cost population, but found that high-cost US Medicare patients more likely had a medical specialist as usual source of care than a primary care physician or surgeon[59]. Finally, high-cost US Medicare patients were only modestly concentrated in hospitals and markets (they were widely distributed through the system). High concentration hospitals (with relatively many high-cost patients) had a 15% higher median cost per claim, were more likely for-profit and teaching hospitals, had lower nurse-to-patient ratios, were more likely to care for the poor, and had higher 30-day readmission rates and lower 30-day mortality rates. High concentration hospital referral regions had higher annual median costs per beneficiary, a larger supply of specialists but equal supply of total physicians, a lower supply of long term care beds, higher hospital care intensity and higher end-of-life spending[18].

Need characteristics

Medical characteristics of high-cost patients are presented in table 2. We categorized medical characteristics to ICD10-chapters. Circulatory diseases, mental and behavioral disorders, endocrine, nutritional and metabolic, diseases of the respiratory system, diseases of the genitourinary system, neoplasms and diseases of the musculoskeletal system and connective tissue were most frequently reported among high-cost patients. The prevalence of chronic disease(s) and multimorbidity were also dominant among high-cost patients. For example, Bynum et al showed that over 26.4% of high-cost US dual eligibles suffered from five or more chronic conditions[21].

Two studies presented medical characteristics across US payers. Both studies showed that high-cost commercial patients had the lowest numbers of comorbidities and that high-cost Medicaid patients had the highest prevalence of mental illness[9, 37]. We further compared

the prevalence of diabetes, congestive heart failure, lung disease, and mental disorders across the studies. The prevalence of diabetes, congestive heart failure and lung disease was relatively low (≈5%-25%) in US commercial and total population studies. In US Medicaid, the prevalence of congestive heart failure and lung disease were relatively high (≈15%-40%; one study reported a prevalence of diabetes and lung disease > 60%[32]), and the prevalence of mental illness was particularly high (≈30%-75%). In US Medicare, the prevalence of diabetes, congestive heart failure and lung disease were highest (≈20%-55%) and the prevalence of mental illness more modest (≈10%-25%). In total populations, approximately 30-40% of high-cost patients were treated for mental illness. Besides, the prevalence of each of the chronic diseases in the Dutch study was comparable with the prevalence in other total population studies. Finally, persistent high-cost patients had a higher number of comorbidities and a higher prevalence of each of the diseases compared to episodic high-cost patients.

High-cost patients were more likely to die, and those in the process of dying were more likely to incur high costs. The mortality differed between payers, much less between countries. The mortality among Danish and Dutch high-cost patients was comparable with the mortality in other total population studies. In US Medicare studies the mortality ranged from 14.2% to 27.4%, compared to 11.7% in one US Medicaid study and 5% to 13% in total populations. In addition, top-1% patients were more likely to die compared to top-5% patients[55, 65] and persistent high-cost patients were more likely to die than episodic high-cost patients[64]. Finally, among US dual eligibles, mortality varied much across age and residence groups; nearly half of dual eligibles aged 65 and older died[21].

Expenditure patterns and healthcare utilization

In each study, costs were heavily concentrated. The top-10% patients roughly accounted for about 68% of costs (range: 55%-77%), the top-5% patients accounted for about 55% of costs

(range: 29%-65%) and top-1% patients for approximately 24% (range: 14%-33%) within a given year. Costs were generally less concentrated in US Medicare, and more concentrated in total populations.

A wide range of parameters were used to describe high-cost patients' healthcare utilization (table 3). Inpatient acute hospital care was most often reported as a primary expenditure category for high-cost patients. In line with this, seventeen studies reported hospitalizations, admissions or inpatient days as important cost drivers. Lieberman found that total spending per beneficiary correlated strongly with the use of inpatient services[53], likewise several studies found that increasing levels of use (i.e. top-1% compared to top-5%) were associated with increasing proportions of spending on (inpatient) hospital care[36, 49, 56, 62, 65, 66]. Guo et al reported that high-cost users consumed more units of each of the service category analyzed, with the exception of laboratory tests[39]; these findings were confirmed elsewhere[44, 56]. In addition, it was found that 91% of high-cost patients received care in multiple care types[57]. Mental care services were listed as expenditure category only in studies of total populations, US Medicaid, and US VA. Finally, one study determined the frequency use of expensive services among high-cost patients: expensive treatments (expensive drugs, intensive care unit treatment, dialysis, transplant care, and DRGs >€30,000) contributed to high cost in approximately one third of top-1% patients, and in less than ten percent of top-2-5% patients[65].

Table 3. Expenditure patterns and utilization of high-cost patients.

Spending category	Number of studies
(Inpatient) hospital care	31 [18, 19, 21, 25, 27-29, 31-33, 36-39, 43, 44, 46, 49, 51-53, 56, 57, 59, 60, 62-66, 68]
Subacute care / postacute care services rehabilitation	11 [9, 25, 27, 28, 32, 33, 46, 56, 57, 59, 66]
Hospitalizations/ admission / patient days/ length of stay	17 [19, 29, 31, 33, 36, 38, 39, 43, 45, 47, 50-52, 56, 58, 65, 68]

Emergency department	12 [19, 37-39, 43, 44, 47, 50, 51, 56, 57, 68]
Outpatient (physician) visits	13 [26, 33, 38, 39, 43, 44, 49, 50, 56, 59-61, 68]
Long term care	11 [21, 25, 27, 28, 32, 33, 40, 43, 51, 61, 66]
Mental health	10 [20, 25, 28, 31, 39, 43, 57, 61, 65, 68]
Physician services	13 [29, 31, 39, 43-45, 56, 58-61, 66, 68]
Intensive care unit	2 [51, 65]
Prescription drugs	16 [22, 26, 28, 29, 32, 36, 38, 39, 44, 46, 50-52, 56, 65, 68]
Persistency	
Subsequent use	13 [21, 22, 28, 30, 34, 36, 37, 42, 53, 55, 60, 61, 64]
Prior use	5 [16, 19, 26, 34, 64]
Persistent users	21 [15, 16, 19, 21, 22, 25, 26, 28, 30, 34, 36, 37, 42, 44, 47, 53, 55, 60, 61, 64, 66]
Prediction of high-cost patients[1]	16 [16, 17, 19, 23-26, 29, 35, 40, 50, 52, 54, 61, 63, 67]

1 An in-depth discussion of prediction models for high costs is beyond the scope of the article (though individual predictors are used throughout the paper). Generally, diagnosis based models outperform prior cost models, and combinations accurately predict high-cost patients. Besides, comorbidity indices also accurately predict high-cost patients, and self-reported health data meaningfully improved existing models.

Four studies quantified the amount of 'preventable' spending (based on preventable emergency department visits and preventable (re-)admissions) among high-cost patients. As shown above, various supply side characteristics were associated with higher preventable costs among high-cost US Medicare patients, and approximately 10% of total costs were preventable[47]. Another study found that 4.8% of US Medicare spending was preventable, and that high-cost patients accounted for 73.8% of preventable spending. Moreover, 43.8% of preventable spending was accounted for by frail elderly, and preventable spending was particularly high for heart failure, pneumonia, COPD/asthma and urinary tract infections[33]. Figueroa et al found that preventable spending differed by insurance type among US non-

elderly: respectively 3,5%, 2.8% and 1.4% of spending were preventable among US Medicaid, US Medicaid managed care and privately insured high-cost patients[32]. Similarly, Graven et al found that proportions of preventable spending differed between payers, and that persistent high-cost patients had higher proportions of preventable spending[37].

Twenty-one studies reported on the persistency of high costs. We found three approaches for studying persistency. First, studies reported *prior* healthcare use and/or reported *posterior* healthcare use for patients with high costs in a given index year. In other studies, persistent high-cost patients were compared to episodic high-cost patients. Spending persistency varied between 24% and 48% for top-5% patients, and between 28% and 45% for top-10% patients. Spending persistence was relatively high in US Medicaid, and relatively low in US Medicare. Increasing persistence was associated with increasing expenditures on all service types[44].

Discussion

We reviewed 55 studies on high-cost patients' characteristics and healthcare utilization, and made comparisons across payers and countries. The studies consistently point to a high prevalence of multiple (chronic) conditions to explain high-cost patients' utilization. Besides, we found a high prevalence of mental illness across all the studies, most notably in US Medicaid and total population studies. We found that various health system characteristics may contribute to high costs. Preventable spending was estimated at maximally ten percent of spending. Furthermore, we found that high costs are associated with increasing age and that clinical diagnoses and utilization patterns varied across age groups. However, still more than half of high-cost patients are younger than 65 years. High costs were associated with higher incomes in the US, but with lower incomes elsewhere. Finally, we confirmed that high-cost

patients are more likely to die, and decedents are more likely to incur high-costs. However, no more than 30% of high-cost patients were in their last year of life.

Strengths and weaknesses

This is the first systematic review of scientific literature on high-cost patients' characteristics and healthcare utilization. Future studies might consider inclusion of grey literature. We included studies of various payer types and countries, allowing comparisons across settings. However, most studies were conducted in the United States and Canada, which limits the generalisability of the findings. Although our comparison across countries did not reveal large differences in mortality or prevalence of common chronic diseases, these analyses were based on a limited number of variables, studies and countries. It is likely that the specific characteristics and utilization of high-cost patients vary across localizations due to a wide range of epidemiological and health system factors. One limitation is that we, because of methodological diversity, did not assess the quality of the included studies, and some studies by design did not control for confounding. To our knowledge, no agreed upon framework exists for risk of bias assessment of the kind of studies included in our review. One limitation in current frameworks for observation/cross-sectional studies is that these are primarily designed for studies that aim to assess intervention effects in comparative studies. The internal validity of the findings in our included studies is mainly contingent upon its ability to control for relevant confounders. However, no consensus exists about what factors should reasonably be controlled for. The external validity of the findings of each of the studies depend upon the breadth of the population studied, and the scope of the costs considered for establishing total costs. Our study selection process was aimed at identifying studies with a broad population studies, and a wide range of costs considered. Finally, the studies used

various approaches for defining the needs and measuring multimorbidity among their populations, which limits the comparability across studies.

Reflections on our findings

Current research in high-cost patients has focused on care redesign of the treatment of patients with multiple chronic morbidities[7, 69]. One contribution of our review is our identification of notable differences in characteristics and utilization across payers and countries. This (clinical) diversity of high-cost patients may even be larger at a local level. Segmentation analysis has been suggested as a method to identify homogenous and meaningful segments of patients with similar characteristics, needs and behavior, that allows for tailored policy[70]. Such segmentation analysis may powerfully inform population health management initiatives. Given the multiple needs and cross-sectoral utilization of high-cost patients, we suggest such analyses should capture both characteristics and utilization as broadly as possible, to fully apprehend high-cost patients care needs and utilization. In the context of high-cost patients, multimorbidity complicates segmentation, and the usefulness of segmentation may depend on the way multimorbidity is dealt with. To illustrate a potent example, Hayes et al defined high-need, high-cost patients as "people having three or more chronic conditions and a functional limitation that makes it hard for them to perform basic daily tasks"[71].

Our findings also reveal several supply side factors that contribute to high costs. However, no firm conclusions can be drawn about the strength of these effects. The apparent limited impact of organizational factors on spending is in line with Andersen's model predictions, where multimorbidity and health status are prime determinants of healthcare costs[72]. However, such findings are surprising given the abundance of evidence for supplier induced demand and medical practice variation[73]. High-cost populations may be too diverse

for studying the impact of organizational factors; for such studies more homogenous populations may be prerequisite.

Four of our included studies estimated the amount of 'preventable' spending among high-cost patients. Preventable spending was estimated at maximally ten percent of spending, which is relatively low compared to the amounts of savings that have been reported elsewhere[8]. Preventable spending was mainly defined as preventable emergency department visits or preventable (re-)admissions, as such echoing the two primary targets of most high-need high-cost programs, including care coordination and disease management. The algorithms used were said to be relatively narrow and could have included other diagnostic categories[37]. Besides, future studies might consider more broad measures of preventable or wasteful spending, and develop algorithms to identify duplicate services, contra-indicated care, unnecessary laboratory testing, unnecessary prolonged hospitalizations, or any other kinds of lower value services.

It was striking that three US studies reported that higher incomes were associated with high costs, whereas other studies found that lower incomes were associated with high costs. These findings may point to disparities in health, the price that some Americans pay for their care, and the reduced accessibility to care of low income patients. This may particularly hold for the uninsured. Besides, these findings suggest tailored interventions for lower income patients may be worthwhile.

Policy and research implications

Based on our findings, we deduced four major segments of high-cost patients for which separate policy may be warranted, including patients in their last year of life, patients experiencing a significant health event who return to stable health (episodically high-cost

patients), patients with mental illness, and patients with persistently high costs characterized by chronic conditions, functional limitations and elder age.

Many interventions have been taken to increase value of end-of-life care. Advance care planning has shown to increase the quality of end-of-life care and decrease costs[74-76]. In addition, health systems might consider strengthening their palliative care systems[77]. Increasing value for episodically high-cost patients requires appropriate pricing of procedures and drugs, for example through selective contracting of providers, reference pricing or competitive bidding[78]. In addition, bundled payments for procedures and associated care may improve care coordination and reduce the use of duplicative or unnecessary services[79]. Multidisciplinary needs assessment and shared decision making may reduce unwarranted variation in expensive procedures. Mental health high-cost patients are known for their medical comorbidities, which suggests these patients might benefit from multidisciplinary cross-sectoral healthcare delivery, for example through collaborative care[80, 81]. Finally, persistent high-cost patients might benefit from a variety of models, including disease management, care coordination, or ambulatory intensive care units, depending on the needs of the population and local circumstances[8, 82-84]. Especially population health management approaches may be beneficial for these populations. Sherry et al. recently examined five community-oriented programs that successfully improved care for high-need, high-cost patients. The five programs shared common attributes, including a 'whole person' orientation, shared leadership, flexible financing and shared cross-system governance structures[85].

One study addressed health beliefs and patient networks among high-cost patients[36]. More of such research is needed as health beliefs may be more amenable to change than other drivers of high costs. One study analyzed the use of expensive treatments by high-cost patients[65]. Better insight in such healthcare utilization patterns is needed to inform interventions and policy aimed at high-cost populations. There is a need for segmentation

variables and logic that is informative at either micro-, meso- and macrolevel. More research is needed to identify determinants of preventable and wasteful spending.

In conclusion, high-cost patients make up the sickest and most complex populations and their high utilization is primarily explained by high levels of chronic and mental illness. High-cost patients are diverse populations and vary across payer types and countries. Tailored interventions are needed to meet the needs of high-cost patients, and to avoid waste of scarce resources.

Acknowledgements: None.

Author contributions: JW drafted the first manuscript and conducted the analyses. JW and PvdW selected eligible studies. JW, PvdW and MT conceptualized the study and interpreted the data. GW and PJ made a substantial contribution to the development of the research question and interpretation and presentation of the findings. All authors provided feedback to, and approved the final manuscript.

Funding statement: The study was conducted as part of a research program funded through the Dutch Ministry of Health. The funding source had no role in study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the manuscript for publication.

Competing interests: None.

Data sharing statement: Detailed forms with extracted data are available from the authors upon request.

References

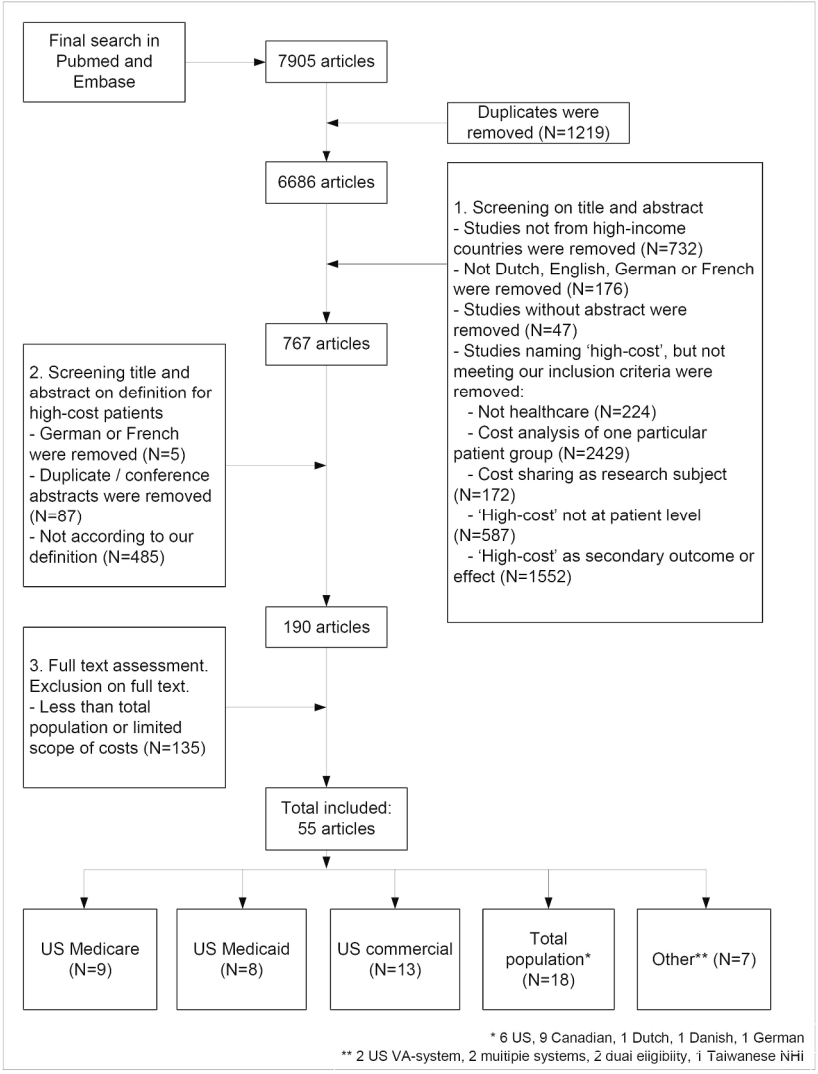
1. Zook, C.J. and F.D. Moore, *High-cost users of medical care.* N Engl J Med, 1980. **302**(18): p. 996-1002.
2. Blumenthal, D., et al., *Caring for High-Need, High-Cost Patients - An Urgent Priority.* N Engl J Med, 2016. **375**(10): p. 909-11.
3. Bodenheimer, T. and A. Fernandez, *High and rising health care costs. Part 4: can costs be controlled while preserving quality?* Ann Intern Med, 2005. **143**(1): p. 26-31.
4. Colla, C.H., et al., *Association Between Medicare Accountable Care Organization Implementation and Spending Among Clinically Vulnerable Beneficiaries.* JAMA Intern Med, 2016. **176**(8): p. 1167-75.
5. Wennberg, J.E., et al., *Inpatient care intensity and patients' ratings of their hospital experiences.* Health Aff (Millwood), 2009. **28**(1): p. 103-12.
6. Blumenthal, D., et al., *Tailoring Complex-Care Management, Coordination, and Integration for High-Need, High-Cost Patients, 2016.*, in *Vital Directions for Health and Health Care Series.* , Discussion paper. National Academy of Medicine. Washington DC., Editor. 2016.
7. Anderson, G.F., et al., *Attributes common to programs that successfully treat high-need, high-cost individuals.* Am J Manag Care, 2015. **21**(11): p. e597-600.
8. Brown, R.S., et al., *Six features of Medicare coordinated care demonstration programs that cut hospital admissions of high-risk patients.* Health Aff (Millwood), 2012. **31**(6): p. 1156-66.
9. Powers, B.W. and S.K. Chaguturu, *ACOs and High-Cost Patients.* N Engl J Med, 2016. **374**(3): p. 203-5.
10. Liberati, A., et al., *The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration.* BMJ, 2009. **339**: p. b2700.
11. Moher, D., et al., *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.* BMJ, 2009. **339**: p. b2535.
12. World bank. [cited 2017; Available from: http://en.wikipedia.org/wiki/World_Bank_high-income_economy
13. Andersen, R.M., *Revisiting the behavioral model and access to medical care: does it matter?* J Health Soc Behav, 1995. **36**(1): p. 1-10.
14. Kominski, G.F., *Changing the U.S. Health Care System: Key Issues in Health Services Policy and Management*. 2013: Wiley.
15. Aldridge, M.D. and A.S. Kelley, *The Myth Regarding the High Cost of End-of-Life Care.* American journal of public health, 2015. **105**(12): p. 2411-2415.
16. Ash, A.S., et al., *Finding future high-cost cases: comparing prior cost versus diagnosis-based methods.* Health Serv Res, 2001. **36**(6 Pt 2): p. 194-206.
17. Bayliss, E.A., et al., *Applying Sequential Analytic Methods to Self-Reported Information to Anticipate Care Needs.* EGEMS (Wash DC), 2016. **4**(1): p. 1258.
18. Beaulieu, N.D., et al., *Concentration of high-cost patients in hospitals and markets.* Am J Manag Care, 2017. **23**(4): p. 233-238.
19. Boscardin, C.K., et al., *Predicting cost of care using self-reported health status data.* BMC health services research, 2015. **15**: p. 406.
20. Buck, J.A., J.L. Teich, and K. Miller, *Use of mental health and substance abuse services among high-cost Medicaid enrollees.* Adm Policy Ment Health, 2003. **31**(1): p. 3-14.
21. Bynum, J.P.W., et al., *High-Cost Dual Eligibles' Service Use Demonstrates The Need For Supportive And Palliative Models Of Care.* Health Aff (Millwood), 2017. **36**(7): p. 1309-1317.
22. Chang, H.Y., et al., *Identifying Consistent High-cost Users in a Health Plan: Comparison of Alternative Prediction Models.* Med Care, 2016. **54**(9): p. 852-9.
23. Charlson, M.E., et al., *Medicaid managed care: how to target efforts to reduce costs.* BMC health services research, 2014. **14**: p. 461.
24. Charlson, M., et al., *The Charlson comorbidity index can be used prospectively to identify patients who will incur high future costs.* PLoS One, 2014. **9**(12): p. e112479.

25. Chechulin, Y., et al., *Predicting patients with high risk of becoming high-cost healthcare users in Ontario (Canada).* Healthc Policy, 2014. **9**(3): p. 68-79.
26. Cohen, S.B., T. Ezzati-Rice, and W. Yu, *The utility of extended longitudinal profiles in predicting future health care expenditures.* Med Care, 2006. **44**(5 Suppl): p. I45-53.
27. Coughlin, T.A., T.A. Waidmann, and L. Phadera, *Among dual eligibles, identifying the highest-cost individuals could help in crafting more targeted and effective responses.* Health Aff (Millwood), 2012. **31**(5): p. 1083-91.
28. Coughlin, T.A. and S.K. Long, *Health care spending and service use among high-cost Medicaid beneficiaries, 2002-2004.* Inquiry, 2009. **46**(4): p. 405-17.
29. Crawford, A.G., et al., *Comparative effectiveness of total population versus disease-specific neural network models in predicting medical costs.* Dis Manag, 2005. **8**(5): p. 277-87.
30. DeLia, D., *Mortality, Disenrollment, and Spending Persistence in Medicaid and CHIP.* Med Care, 2017. **55**(3): p. 220-228.
31. de Oliveira, C., et al., *Patients With High Mental Health Costs Incur Over 30 Percent More Costs Than Other High-Cost Patients.* Health Aff (Millwood), 2016. **35**(1): p. 36-43.
32. Figueroa, J.F., et al., *Characteristics and spending patterns of high cost, non-elderly adults in Massachusetts.* Healthc (Amst), 2017.
33. Figueroa, J.F., et al., *Concentration of Potentially Preventable Spending Among High-Cost Medicare Subpopulations: An Observational Study.* Ann Intern Med, 2017.
34. Fitzpatrick, T., et al., *Looking Beyond Income and Education: Socioeconomic Status Gradients Among Future High-Cost Users of Health Care.* Am J Prev Med, 2015. **49**(2): p. 161-71.
35. Fleishman, J.A. and J.W. Cohen, *Using information on clinical conditions to predict high-cost patients.* Health Serv Res, 2010. **45**(2): p. 532-52.
36. Ganguli, I., R. Thompson, and T.G. Ferris, *What can five high cost patients teach us about health care spending?* Journal of General Internal Medicine, 2016. **1)**: p. S469.
37. Graven, P.F., et al., *Preventable acute care spending for high-cost patients across payer types.* Journal of Health Care Finance, 2016. **42**(3).
38. Guilcher, S.J., et al., *Who Are the High-Cost Users? A Method for Person-Centred Attribution of Health Care Spending.* PLoS One, 2016. **11**(3): p. e0149179.
39. Guo, J.J., et al., *Characteristics and risk factors associated with high-cost medicaid recipients.* Manag Care Interface, 2004. **17**(10): p. 20-27.
40. Hartmann, J., et al., *Analysing predictors for future high-cost patients using German SHI data to identify starting points for prevention.* Eur J Public Health, 2016. **26**(4): p. 549-55.
41. Hensel, J.M., et al., *Rates of Mental Illness and Addiction among High-Cost Users of Medical Services in Ontario.* Can J Psychiatry, 2016. **61**(6): p. 358-66.
42. Hirth, R.A., et al., *New Evidence on the Persistence of Health Spending.* Medical Care Research and Review, 2015. **72**(3): p. 277-297.
43. Hunter, G., et al., *Health Care Utilization Patterns Among High-Cost VA Patients With Mental Health Conditions.* Psychiatr Serv, 2015. **66**(9): p. 952-8.
44. Hwang, W., et al., *Persistent high utilization in a privately insured population.* Am J Manag Care, 2015. **21**(4): p. 309-16.
45. Izad Shenas, S.A., et al., *Identifying high-cost patients using data mining techniques and a small set of non-trivial attributes.* Comput Biol Med, 2014. **53**: p. 9-18.
46. Joynt, K.E., et al., *Segmenting high-cost Medicare patients into potentially actionable cohorts.* Healthc (Amst), 2017. **5**(1-2): p. 62-67.
47. Joynt, K.E., et al., *Contribution of preventable acute care spending to total spending for high-cost Medicare patients.* JAMA, 2013. **309**(24): p. 2572-8.
48. Krause, T.M., et al., *Future expenditure risk of silent members: a statistical analysis.* BMC Health Serv Res, 2016. **16**: p. 319.
49. Ku, L.J., M.J. Chiou, and L.F. Liu, *Variations in the persistence of health expenditures and the implications for the design of capitation payments in Taiwan.* J Health Serv Res Policy, 2015. **20**(3): p. 146-53.

50. Lauffenburger, J.C., et al., *Longitudinal Patterns of Spending Enhance the Ability to Predict Costly Patients: A Novel Approach to Identify Patients for Cost Containment.* Med Care, 2017. **55**(1): p. 64-73.
51. Lee, N.S., et al., *High-Cost Patients: Hot-Spotters Don't Explain the Half of It.* J Gen Intern Med, 2017. **32**(1): p. 28-34.
52. Leininger, L.J., et al., *Predicting high-need cases among new Medicaid enrollees.* The American journal of managed care, 2014. **20**(9): p. e399-e407.
53. Lieberman, S.M., et al., *Reducing the growth of Medicare spending: geographic versus patient-based strategies.* Health Aff (Millwood), 2003. **Suppl Web Exclusives**: p. W3-603-13.
54. Meenan, R.T., et al., *Using risk-adjustment models to identify high-cost risks.* Med Care, 2003. **41**(11): p. 1301-12.
55. Monheit, A.C., *Persistence in health expenditures in the short run: prevalence and consequences.* Med Care, 2003. **41**(7 Suppl): p. III53-III64.
56. Pritchard, D., et al., *What Contributes Most to High Health Care Costs? Health Care Spending in High Resource Patients.* J Manag Care Spec Pharm, 2016. **22**(2): p. 102-9.
57. Rais, S., et al., *High-cost users of Ontario's healthcare services.* Healthc Policy, 2013. **9**(1): p. 44-51.
58. Reid, R., et al., *Conspicuous consumption: characterizing high users of physician services in one Canadian province.* J Health Serv Res Policy, 2003. **8**(4): p. 215-24.
59. Reschovsky, J.D., et al., *Following the money: factors associated with the cost of treating high-cost Medicare beneficiaries.* Health Serv Res, 2011. **46**(4): p. 997-1021.
60. Riley, G.F., *Long-term trends in the concentration of Medicare spending.* Health Aff (Millwood), 2007. **26**(3): p. 808-16.
61. Robst, J., *Developing Models to Predict Persistent High-Cost Cases in Florida Medicaid.* Popul Health Manag, 2015. **18**(6): p. 467-76.
62. Rosella, L.C., et al., *High-cost health care users in Ontario, Canada: demographic, socio-economic, and health status characteristics.* BMC Health Serv Res, 2014. **14**: p. 532.
63. Snider, J.T., et al., *Identifying patients at risk for high medical costs and good candidates for obesity intervention.* Am J Health Promot, 2014. **28**(4): p. 218-27.
64. Tamang, S., et al., *Predicting patient 'cost blooms' in Denmark: a longitudinal population-based study.* BMJ Open, 2017. **7**(1): p. e011580.
65. Wammes, J.J.G., et al., *Characteristics and healthcare utilisation patterns of high-cost beneficiaries in the Netherlands: a cross-sectional claims database study.* BMJ Open, 2017. **7**(11): p. e017775.
66. Wodchis, W.P., P.C. Austin, and D.A. Henry, *A 3-year study of high-cost users of health care.* Cmaj, 2016. **188**(3): p. 182-8.
67. Zhao, Y., et al., *Identifying future high-cost cases through predictive modeling.* Disease Management and Health Outcomes, 2003. **11**(6): p. 389-397.
68. Zulman, D.M., et al., *Multimorbidity and healthcare utilisation among high-cost patients in the US Veterans Affairs Health Care System.* BMJ Open, 2015. **5**(4): p. e007771.
69. Bleich, S.N., et al., *Systematic Review of Programs Treating High-Need and High-Cost People With Multiple Chronic Diseases or Disabilities in the United States, 2008-2014.* Prev Chronic Dis, 2015. **12**: p. E197.
70. Vuik, S.I., E.K. Mayer, and A. Darzi, *Patient Segmentation Analysis Offers Significant Benefits For Integrated Care And Support.* Health Aff (Millwood), 2016. **35**(5): p. 769-75.
71. Hayes, S.L., et al., *High-Need, High-Cost Patients: Who Are They and How Do They Use Health Care? A Population-Based Comparison of Demographics, Health Care Use, and Expenditures.* Issue Brief (Commonw Fund), 2016. **26**: p. 1-14.
72. Heider, D., et al., *Health care costs in the elderly in Germany: an analysis applying Andersen's behavioral model of health care utilization.* BMC Health Serv Res, 2014. **14**: p. 71.
73. Wennberg, J.E., *Tracking Medicine:A Researcher's Quest to Understand Health Care: A Researcher's Quest to Understand Health Care*. 2010: Oxford University Press, USA.

74. Brinkman-Stoppelenburg, A., J.A. Rietjens, and A. van der Heide, *The effects of advance care planning on end-of-life care: a systematic review.* Palliat Med, 2014. **28**(8): p. 1000-25.
75. Dixon, J., T. Matosevic, and M. Knapp, *The economic evidence for advance care planning: Systematic review of evidence.* Palliat Med, 2015. **29**(10): p. 869-84.
76. Klingler, C., J. in der Schmitten, and G. Marckmann, *Does facilitated Advance Care Planning reduce the costs of care near the end of life? Systematic review and ethical considerations.* Palliat Med, 2016. **30**(5): p. 423-33.
77. World Health Organization, *Strengthening of palliative care as a component of integrated treatment throughout the life course.* Journal of pain & palliative care pharmacotherapy, 2014. **28**(2): p. 130-4.
78. Stadhouders, N., et al., *Policy options to contain healthcare costs: a review and classification.* Health Policy, 2016. **120**(5): p. 486-94.
79. Miller, D.C., et al., *Large variations in Medicare payments for surgery highlight savings potential from bundled payment programs.* Health Aff (Millwood), 2011. **30**(11): p. 2107-15.
80. Camacho, E.M., et al., *Long-term cost-effectiveness of collaborative care (vs usual care) for people with depression and comorbid diabetes or cardiovascular disease: a Markov model informed by the COINCIDE randomised controlled trial.* BMJ Open, 2016. **6**(10): p. e012514.
81. Druss, B.G. and E.R. Walker, *Mental disorders and medical comorbidity*, in *Research Synthesis Report 21*. 2011, Robert Wood Johnson Foundation: Princeton, NJ.
82. Bodenheimer, T., *Strategies to Reduce Costs and Improve Care for High-Utilizing Medicaid Patients: Reflections on Pioneering Programs*. 2013, Centre for Health Care Strategies.
83. Tricco, A.C., et al., *Effectiveness of quality improvement strategies for coordination of care to reduce use of health care services: a systematic review and meta-analysis.* CMAJ, 2014. **186**(15): p. E568-78.
84. Vrijhoef, B. and R. Thorlby, *Developing care for a changing population: supporting patients with costly, complex needs*. 2016, Nuffield Trust.
85. Sherry, M., et al., *Bridging the Silos of Service Delivery for High-Need, High-Cost Individuals.* Popul Health Manag, 2016.

Figure 1 legend: Flow diagram of article selection.



Flow diagram of article selection.

210x297mm (300 x 300 DPI)

Appendix 1. Final search strategy.

Pubmed:
(((((((High-cost*)) OR (high spending)) OR (Costliest)) OR (highest-cost*))) AND ((((((Patient*)) OR (Individual*)) OR (Benefici*)) OR (Person*)) OR (user*)) NOT medline[sb])) OR (((((("Economics, Hospital"[Mesh]) OR "Economics, Medical"[Mesh]) OR "Health Care Sector"[Mesh])) OR ("Costs and Cost Analysis"[Mesh]))) AND (((((((High-cost*)) OR (high spending)) OR (Costliest)) OR (highest-cost*))) AND ((((((Patient*)) OR (Individual*)) OR (Benefici*)) OR (Person*)) OR (user*))))

Embase:

1	(high-cost* or high spending or Costliest or highest-cost*).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
2	(patient* or individual* or benefici* or person* or user*).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
3	"hospital cost"/ or "health care cost"/ or "cost"/ or economic aspect/ or "hospital utilization"/ or medicare/ or exp medicaid/
4	1 and 2 and 3
5	((high-cost* or high spending or Costliest or highest-cost*) adj3 (patient* or individual* or benefici* or person* or user*)).mp.
6	4 or 5

Author(s), country	Key points of the article
Aldridge and Kelly[1], United States	The majority of decedents were in the high-cost group, however the majority of high-cost patients were not in their last year of life. Not only is this group small (11%), the window of time for a significant impact on costs is limited by the patients' life expectancy. Findings confirm the need to focus on those with serious chronic illnesses, functional debility, and persistently high costs.
Ash et al.[2], United States	Diagnosis-based risk models are at least as powerful as prior cost for identifying people who will be expensive. Combined cost and diagnostic data were even more powerful and more operationally useful, especially because the diagnostic information identifies the medical problems that may be managed to achieve better out comes and lower costs.
Bayliss et al.[3], United States	Self-reported health status, functional limitations, medication use, presence of 0-4 chronic conditions, self-reported ED use during the prior year, lack of prior insurance, age, gender, and deductible-based insurance product were predictive for high costs.
Beaulieu et al.[4], United States	High-cost patients are only modestly concentrated in specific hospitals and markets. The hospitals and markets that disproportionately care for high-cost beneficiaries were markedly different than those that cared for fewer such patients: these hospitals were either academic teaching or for-profit institutions operating in urban settings and serve a greater proportion of low-income patients. Concentrated markets had a greater supply of specialists and a lower supply of long-term care beds. Spending in the last 6 months of life was also significantly higher in high-cost concentration HRRs.
Boscardin et al.[5], United States	In addition to demographic characteristics and health service use, self-report of the presence of specific health conditions were predictive for high costs.
Buck et al.[6], United States	Mental health/substance abuse service users constitute 11% of all Medicaid enrollees, but make up nearly a third of high-cost enrollees. Their use of non-mental health/substance abuse services is more important than their use of MH/SA services in determining their high-cost status. Adults account for two third of this high-cost MH/SA group, and they most frequently qualify for Medicaid through disability-related eligibility categories.
Bynum et al.[7], United States	High combined Medicare and Medicaid spending are found in two distinct groups of high-cost dual eligibles: older beneficiaries who are nearing their end of life, and younger beneficiaries with sustained need for functional supports. High-cost dual eligibles often use costly inpatient settings, including acute care hospitals and inpatient long-term care services, in addition to nursing homes. 57% of high-cost dual eligibles reside in the community, not in long term care.
Chang et al.[8], United States	Consistent high-cost users had higher total and pharmacy costs, and more chronic and psychosocial conditions than episodic high-cost users.
Charlson et al. [9], United States	The comorbidity index was significantly correlated with the top 5% and top 10% of costs for the pooled sample, as well as for adults and children separately. Comorbidity can be used to identify beneficiaries most likely to incur high costs.
Charlson et al. [10], United States	Prior year costs, prior year comorbidity, prior year DCG, and prior year hospitalizations were all evaluated as predictors of upper 5% and upper 10% of subsequent (2010) costs in separate models controlling for age, gender and mental health diagnosis. In adults, the comorbidity index was equivalent to DCG and prior cost in predicting the top 5% and 10% of cost, while prior hospitalization had much lower ability to identify such patients.
Chechulin et al. [11], Canada	Age was a strong predictor of high costs, and as the material and social deprivation index increases, the risk of becoming high-cost increased. Males were more likely to incur high costs, and degree of rurality was also linked to high costs. Current and past healthcare utilization were the strongest predictors for high use. Several influential were significantly associated with high costs.
Cohen et al.[12], United States	Prior year expenditures, frequency of prescribed medication purchases, the number of office based provider visits, activity limitations and health status were the most significant predictors for high costs. Other measures that were significantly related to high costs were age, gender, marital status, family income, living alone, and the presence of an infectious or respiratory condition. Predictive capacity of models did not suffer when restricted to a single year of prior information.
Coughlin et al.[13], United States	20% of dual eligibles account for more than 60% of combined Medicaid and Medicare spending on the dual population. Subgroups were found among these high-cost population. Fewer than 1% of dual eligibles were in high-cost categories for both Medicare and Medicaid. Dual eligibles are a highly diverse group in terms of their spending. Being a dual eligible is not necessarily synonymous with high spending.
Coughlin and Long [14], United States	A high degree of spending persistence was observed: 57.9% of those in the top-10% remained in the top-10% in the two subsequent years. Two distinct high-cost groups were identified, those with persistently high costs and those with episodically high costs, each with different services driving their costs.
Crawford et al.[15], United States	The following predictive factors, listed in descending order according to the magnitude of their importance statistics, were related to high costs: total medical costs, physician costs, prescription drug costs, number of unique diagnoses, age, number of prescription drug claims, number of unique procedures, hypertension symptoms, CAD symptoms, inpatient costs, and diabetes symptoms.

DeLia[16], United States	One forth of extreme spenders remained in that category in the three subsequent years. Almost all were blind, disabled and aged, the majority have a developmental disability, central nervous system diagnosis, or psychiatric diagnosis. Persistently high spenders were also more likely to be men, >40 years old, living in a nursing facility, or having a higher CDPS score.
de Oliveira et al.[17], Canada	Mental health high-cost patients incurred 30% higher costs than other high-cost populations. They were younger, lived in poorer neighboorhouds, and had different health care utilization patterns.
Figueroa et al.[18], United States	Characteristics and likelihood of high costs vary by major type of insurance. Nearly 1 in 5 Mediciad insured patients was likely to be high-cost (top-10%), these patients were more likely to be medically complex, with more chronic diseases and mental health health/substance abuse problems. Additionally, patterns of spending varied by major type of insurance.
Figueroa et al.[19], United States	About 5% of total health care spending incurred by Medicare beneficiaries was potentially preventable, and most of this spending was incurred by high-cost patients. Large variations existed across high-cost subgroups. The high-cost frail elderly group accounted for nearly half of all potentially preventable spending after admissions for ACSCs or potentially avoidable ED visits. This spending was particularly high for heart failure, pneumonia, chronic obstructive pulmonary disease or asthma, and urinary tract infections.
Fitzpatrick et al.[20], Canada	Future high costs status was most strongly associated with food insecurity, personal income, and non-homeownership. Living in highly deprived or low ethnic concentration neighborhoods also increased the odds of becoming an HCU.
Fleishmann et al.[21], United States	Medical condition information substantially improved prediction of high expenditures beyond gender and age, with the DCG risk score providing the greatest improvement in prediction. The count of chronic conditions, self-reported health status, and functional limitations were significantly associated with future high expenditures, controlling for DCG score.
Ganguli et al.[22], United States	Complex medical issues, physical disability/frailty, and mental illness/substance was linked with increased costs, while socioeconomic status, social network, activation, and trust in clinicians and the health system appeared to increase or decrease costs depending on context. Trust seemed to modify the interaction between patient activation and cost.
Graven et al.[23], United States	Among the top-10%, 5.6%, 1.9%, and 3.8% was attributable to spending on preventable services for Medicaid, commercial, and Medicare Advantage patients, respectively. In the third year of spending among persistently high-cost patients in Medicaid, commercial and Medicaid advantage programs, cost were decreased by 11%, 25.6% and 30.6% respectively.
Guilcher et al.[24], Canada	This study provides a novel methodological approach to categorize high-cost health system users into meaningful person-centered episodes. The most common clinical grouping categories to start a person-centered episode of care were Planned Surgical, Unplanned Medical and Post-Acute Admission Events. Inpatient acute and inpatient rehabilitation accounted for the largest proportions of costs.
Guo et al.[25], United States	High-cost patients not only utilized more costly services, and more units of service per recipient, but also had higher per-unit costs for each of the service categories. The following groups had the highest odds of being a high-cost users: dying, disabled, urban resident, and male.
Hartmann et al.[26], Germany	Several predictors were related to high costs, including insurance status (dependent coverage in particular), prior expenditures, home nursing, chronic diseases and multimorbidity, mental and behavioral disorders, musculoskeletal disorders, respiratory system disorders, cardiovascular diseases, and metabolic diseases.
Hensel et al.[27], Canada	Seventeen percent of the most costly users had a prior diagnosis of a psychotic, major mood, or substance use disorder, and nearly 40% when anxiety and other disorders were included. The rate of mental illness and addiction rose incrementally across increasing user cost categories.
Hirth et al.[28], United States	Individuals' positions within the spending distribution vary over time, but considerable persistence exists, particularly clear at the lower end of the spending distribution, but also at the top persistence is considerable. Many characteristics retained predictive power for future spending, including age, gender and a variety of medical conditions.
Hunter et al.[29], United States	Approximately half of high-cost patients had at least one psychiatric diagnosis, and of these 49% had two or more psychiatric diagnoses. Utilization and costs of mental health and medical-surgical care differed among various groups of high-cost patients with mental health conditions.
Hwang et al.[30], United States	Persistent high users had higher overall disease burden due to multiple chronic conditions and incurred significantly higher expenses in medication and professional services.
Izad Shenas et al.[31], United	Data mining techniques, including neural networks and decision trees, were used to identify non-trivial attributes of high-cost patients. Identified attributes were overall health perception, age, history of blood cholesterol check, history of physical/ sensory/ mental limitations, and history of colonic prevention measures.
Joynt et al.[32], United States	High-cost beneficiaries were segmented into clinically relevant groups, including frail elders, those with disabilities or ESRD under the age 65, beneficiaries with chronic illnesses, and those who were relatively healthy at baseline. Frail elders were most likely to incur high costs, nearly half of the frail beneficiaries incurred high costs, and they comprised 40% of the high-cost population. Overall patterns of spending were relatively similar across high-cost segments, with inpatient spending contributing the largest share in general.

Joynt et al.[33], United States	Approximately 10% of the costs for high-cost Medicare patients were deemed potentially preventable. The percentage was slightly higher for the persistently high-cost cohort. Hospital referral regions with a higher primary care or physician supply had higher annual preventable costs per capita.
Krause et al.[34], United States	Silent-members are members of a medical health plan who submit no claims for healthcare services in a benefit year despite 12 months of continuous-enrollment. This study found that silent members who seek care in subsequent years have a greater probability of becoming high-expenditure claimants than those with low-expenditure experience.
Ku et al.[35], Taiwan	Of the top-10%, 39% remained high-cost in the year thereafter. NHI expenditure percentiles, and all chronic conditions significantly predicted future expenditures.
Lauffenburger et al.[36], United States	High-cost patients had higher mean comorbidity scores (measured using four risk adjustment measures). Trajectory modeling may be a useful way to predict costly patients that could be implementable by payers to improve cost-containment efforts.
Lee et al., [37]United States	Five distinct phenotypes of high-cost patients with diverse drivers of cost were identified. Besides, "hot-spotters" (those with four or more admissions) were quantified. They accounted for 9% of high-cost patients and 19% of that population's costs. The majority of "hot-spotters" were in the cluster of patients who had 'frequent care'.
Leininger et al.[38], United States	Self reported health measures were meaningful predictors of high costs, this included individual conditions, behavioral variables, prescription drug use, previous year utilization, and access to care measures.
Lieberman et al.[39], United States	This paper explored the potential of two alternative approaches for reducing the rate of growth in Medicare spending. Viewed from a budgetary perspective, concentration in Medicare spending suggests the importance of focusing on high-spending patients. Spending per beneficiary correlated strongly with inpatient use. The prevalence of serious chronic conditions is higher among high-spending beneficiaries. A high-cost patient was five times more likely to die. However, only one fifth died at the end of the year.
Meenan[40], United States	This study evaluated a variety of risk models to predict high-cost patients. To predict top-1% and top-0.5%, ACGs, DCGs, GRAM, and Prior-expense were very comparable in overall discrimination (AUCs, 0.83– 0.86). DCGs captured the most "high-cost" dollars among enrollees with asthma, diabetes, and depression; predictive performance among demographic groups (Medicaid members, members over 64, and children under 13) varied across models.
Monheit[41], United States	A sizeable minority of high expenditure cases exhibits persistently high expenditures in the short run. However, when all persons in a top expenditure percentile are considered, health expenditures do begin to regress to the mean over time as a majority of high spenders move to lower positions throughout the expenditure distribution.
Powers and Chaguturu[42], United States	Little is known about variation in clinical characteristics and care-utilization patterns among payer-defined groups. The costliest 1% of Medicare patients had an average of 8 co-occurring chronic conditions. In Medicaid, high-cost patients also had several co-occurring chronic conditions (five on average) but there was a striking prevalence of mental health disorders. In commercial populations, high-cost patients had fewer chronic conditions and were more likely to have disease risk factors than end-stage sequelae. Drivers of high costs in this population included catastrophic injuries, neurologic events, and need for specialty pharmaceuticals.
Pritchard et al.[43], United States	Spending pattern for high-cost patients differs considerably from the general population. The absolute expenditures for each place of service were increased, and the share of spending on inpatient services is significantly higher in high-cost patients, while the share of expenditures attributed to major outpatient places of service and pharmacy are lower. Common health conditions, such as back disorders and osteoarthritis, contribute a large share of expenditures, but other conditions such as chronic renal failure, graft rejection, and some cancers accounted for disproportionately higher expenditures in high-cost patients.
Rais et al.[44], Canada	Males are more costly than females. Seniors accounted for the majority of high-cost users and costs, but the average costs per patients decreased with age. Of the different clinical conditions, circulatory system conditions incurred the most costs.
Reid et al.[45], Canada	High-cost users are overwhelmingly characterized by multiple and complex health problems. This relatively small group accounted for a disproportionate share of primary care and specialist encounters as well as inpatient days.
Reschovsky et al.[46], United States	Among high-cost patients, health was the predominant predictor of costs, with most physician and practice and many market factors (including provider supply) insignificant or only weakly associated with high costs. Beneficiaries whose usual physician was a medical specialist or reported inadequate office visit time, medical specialist supply, provider for-profit status, care fragmentation, and Medicare fees were associated with higher costs.
Riley [47], United States	Annual expenditures became less concentrated over time, although the year-to-year persistence of person-level high costs remained strong. There was an increase in the prevalence of chronic conditions among high-cost beneficiaries. Spending concentration in Medicare decreased over time, perhaps due to 1) trends in longevity and medical expenses (increasing life expectancy has had the effect of spreading the same level of healthcare costs over a greater number of years; as age of death increases, lifetime Medicare costs increase only slightly), 2) expensive technologies

	are increasingly used on less sick patients, or 3) trends in disability.
Robst[48], United States	High costs were very persistent, as a high percentage of individuals were high-cost cases for multiple years. In addition, individuals receiving ICF-mental retardation services were very likely to have persistent high costs. Individuals with 1 or more inpatient stays in the base year were less likely to remain high cost in the future. Most high-cost cases had multiple diagnoses.
Rosella et al.[49], Canada	High-cost patients tended to be older with multiple comorbidities and were more likely to be white, female and have lower household income. Risky behaviors were not overwhelmingly drivers of short term high-cost, but this is likely an artifact.
Snider et al.[50], United States	A logistic model was used to capture the effect of BMI on the risk of high future medical spending. Individuals in all obesity classes have higher risk of high medical spending in the following year compared to normal weight patients (BMI ≤ 25).
Tamang et al.[51], Denmark	Cost bloomers (those who move from the lower to the upper percentile in one year) represented the majority of high-cost patients. They were younger, had less comorbidity, lower mortality and fewer chronic conditions. Diverse population health data, in conjunction with modern statistical learning methods for analyzing large data sets, can improve prediction of future high-cost patients over standard diagnosis-based tools, especially for cost-bloom prediction task.
Wammes et al.[52], Netherlands	Expensive treatments, most cost-incurring condition and age proved to be informative variables for studying high-cost patients. Expensive care use (expensive drugs, ICU treatment, dialysis, transplant care and DRG >€30 000) contributed to high costs in one third of top 1% beneficiaries and in less than 10% of top 2%–5% beneficiaries. High-cost beneficiaries were overwhelmingly treated for diseases of circulatory system, neoplasms and mental disorders. More than 50% of high-cost beneficiaries were 65 years of age or younger, and average costs decreased sharply with higher age within the top 1% population.
Wodchis et al.[53], Canada	High health care costs were related to a diverse set of patient health care needs and were incurred in a wide array of healthcare settings. Analyses showed moderate stability in health care costs for individuals over a 3-year period. High-cost spending patterns and conditions varied across age groups.
Zhao et al.[54], United States	This study evaluated three models to predict high-cost patients, including a DCG-model, a prior cost model, and a prior plus DCG-model (combo model). The DCG-model and combo model outperformed the prior cost model.
Zulman et al.[55], United States	Multisystem morbidity is common in high-cost patients, approximately two-thirds have chronic conditions affecting three or more body systems. While some patients with cancer or mental illness may benefit from disease specific interventions, the majority most likely require programs that address their heterogeneous health needs.

References

1. Aldridge, M.D. and A.S. Kelley, *The Myth Regarding the High Cost of End-of-Life Care.* American journal of public health, 2015. **105**(12): p. 2411-2415.
2. Ash, A.S., et al., *Finding future high-cost cases: comparing prior cost versus diagnosis-based methods.* Health Serv Res, 2001. **36**(6 Pt 2): p. 194-206.
3. Bayliss, E.A., et al., *Applying Sequential Analytic Methods to Self-Reported Information to Anticipate Care Needs.* EGEMS (Wash DC), 2016. **4**(1): p. 1258.
4. Beaulieu, N.D., et al., *Concentration of high-cost patients in hospitals and markets.* Am J Manag Care, 2017. **23**(4): p. 233-238.
5. Boscardin, C.K., et al., *Predicting cost of care using self-reported health status data.* BMC health services research, 2015. **15**: p. 406.
6. Buck, J.A., J.L. Teich, and K. Miller, *Use of mental health and substance abuse services among high-cost Medicaid enrollees.* Adm Policy Ment Health, 2003. **31**(1): p. 3-14.
7. Bynum, J.P.W., et al., *High-Cost Dual Eligibles' Service Use Demonstrates The Need For Supportive And Palliative Models Of Care.* Health Aff (Millwood), 2017. **36**(7): p. 1309-1317.
8. Chang, H.Y., et al., *Identifying Consistent High-cost Users in a Health Plan: Comparison of Alternative Prediction Models.* Med Care, 2016. **54**(9): p. 852-9.
9. Charlson, M.E., et al., *Medicaid managed care: how to target efforts to reduce costs.* BMC health services research, 2014. **14**: p. 461.
10. Charlson, M., et al., *The Charlson comorbidity index can be used prospectively to identify patients who will incur high future costs.* PLoS One, 2014. **9**(12): p. e112479.
11. Chechulin, Y., et al., *Predicting patients with high risk of becoming high-cost healthcare users in Ontario (Canada).* Healthc Policy, 2014. **9**(3): p. 68-79.

12. Cohen, S.B., T. Ezzati-Rice, and W. Yu, *The utility of extended longitudinal profiles in predicting future health care expenditures.* Med Care, 2006. **44**(5 Suppl): p. I45-53.
13. Coughlin, T.A., T.A. Waidmann, and L. Phadera, *Among dual eligibles, identifying the highest-cost individuals could help in crafting more targeted and effective responses.* Health Aff (Millwood), 2012. **31**(5): p. 1083-91.
14. Coughlin, T.A. and S.K. Long, *Health care spending and service use among high-cost Medicaid beneficiaries, 2002-2004.* Inquiry, 2009. **46**(4): p. 405-17.
15. Crawford, A.G., et al., *Comparative effectiveness of total population versus disease-specific neural network models in predicting medical costs.* Dis Manag, 2005. **8**(5): p. 277-87.
16. DeLia, D., *Mortality, Disenrollment, and Spending Persistence in Medicaid and CHIP.* Med Care, 2017. **55**(3): p. 220-228.
17. de Oliveira, C., et al., *Patients With High Mental Health Costs Incur Over 30 Percent More Costs Than Other High-Cost Patients.* Health Aff (Millwood), 2016. **35**(1): p. 36-43.
18. Figueroa, J.F., et al., *Characteristics and spending patterns of high cost, non-elderly adults in Massachusetts.* Healthc (Amst), 2017.
19. Figueroa, J.F., et al., *Concentration of Potentially Preventable Spending Among High-Cost Medicare Subpopulations: An Observational Study.* Ann Intern Med, 2017.
20. Fitzpatrick, T., et al., *Looking Beyond Income and Education: Socioeconomic Status Gradients Among Future High-Cost Users of Health Care.* Am J Prev Med, 2015. **49**(2): p. 161-71.
21. Fleishman, J.A. and J.W. Cohen, *Using information on clinical conditions to predict high-cost patients.* Health Serv Res, 2010. **45**(2): p. 532-52.
22. Ganguli, I., R. Thompson, and T.G. Ferris, *What can five high cost patients teach us about health care spending?* Journal of General Internal Medicine, 2016. **1)**: p. S469.
23. Graven, P.F., et al., *Preventable acute care spending for high-cost patients across payer types.* Journal of Health Care Finance, 2016. **42**(3).
24. Guilcher, S.J., et al., *Who Are the High-Cost Users? A Method for Person-Centred Attribution of Health Care Spending.* PLoS One, 2016. **11**(3): p. e0149179.
25. Guo, J.J., et al., *Characteristics and risk factors associated with high-cost medicaid recipients.* Manag Care Interface, 2004. **17**(10): p. 20-27.
26. Hartmann, J., et al., *Analysing predictors for future high-cost patients using German SHI data to identify starting points for prevention.* Eur J Public Health, 2016. **26**(4): p. 549-55.
27. Hensel, J.M., et al., *Rates of Mental Illness and Addiction among High-Cost Users of Medical Services in Ontario.* Can J Psychiatry, 2016. **61**(6): p. 358-66.
28. Hirth, R.A., et al., *New Evidence on the Persistence of Health Spending.* Medical Care Research and Review, 2015. **72**(3): p. 277-297.
29. Hunter, G., et al., *Health Care Utilization Patterns Among High-Cost VA Patients With Mental Health Conditions.* Psychiatr Serv, 2015. **66**(9): p. 952-8.
30. Hwang, W., et al., *Persistent high utilization in a privately insured population.* Am J Manag Care, 2015. **21**(4): p. 309-16.
31. Izad Shenas, S.A., et al., *Identifying high-cost patients using data mining techniques and a small set of non-trivial attributes.* Comput Biol Med, 2014. **53**: p. 9-18.
32. Joynt, K.E., et al., *Segmenting high-cost Medicare patients into potentially actionable cohorts.* Healthc (Amst), 2017. **5**(1-2): p. 62-67.
33. Joynt, K.E., et al., *Contribution of preventable acute care spending to total spending for high-cost Medicare patients.* JAMA, 2013. **309**(24): p. 2572-8.
34. Krause, T.M., et al., *Future expenditure risk of silent members: a statistical analysis.* BMC Health Serv Res, 2016. **16**: p. 319.
35. Ku, L.J., M.J. Chiou, and L.F. Liu, *Variations in the persistence of health expenditures and the implications for the design of capitation payments in Taiwan.* J Health Serv Res Policy, 2015. **20**(3): p. 146-53.
36. Lauffenburger, J.C., et al., *Longitudinal Patterns of Spending Enhance the Ability to Predict Costly Patients: A Novel Approach to Identify Patients for Cost Containment.* Med Care, 2017. **55**(1): p. 64-73.

37. Lee, N.S., et al., *High-Cost Patients: Hot-Spotters Don't Explain the Half of It.* J Gen Intern Med, 2017. **32**(1): p. 28-34.
38. Leininger, L.J., et al., *Predicting high-need cases among new Medicaid enrollees.* The American journal of managed care, 2014. **20**(9): p. e399-e407.
39. Lieberman, S.M., et al., *Reducing the growth of Medicare spending: geographic versus patient-based strategies.* Health Aff (Millwood), 2003. **Suppl Web Exclusives**: p. W3-603-13.
40. Meenan, R.T., et al., *Using risk-adjustment models to identify high-cost risks.* Med Care, 2003. **41**(11): p. 1301-12.
41. Monheit, A.C., *Persistence in health expenditures in the short run: prevalence and consequences.* Med Care, 2003. **41**(7 Suppl): p. III53-III64.
42. Powers, B.W. and S.K. Chaguturu, *ACOs and High-Cost Patients.* N Engl J Med, 2016. **374**(3): p. 203-5.
43. Pritchard, D., et al., *What Contributes Most to High Health Care Costs? Health Care Spending in High Resource Patients.* J Manag Care Spec Pharm, 2016. **22**(2): p. 102-9.
44. Rais, S., et al., *High-cost users of Ontario's healthcare services.* Healthc Policy, 2013. **9**(1): p. 44-51.
45. Reid, R., et al., *Conspicuous consumption: characterizing high users of physician services in one Canadian province.* J Health Serv Res Policy, 2003. **8**(4): p. 215-24.
46. Reschovsky, J.D., et al., *Following the money: factors associated with the cost of treating high-cost Medicare beneficiaries.* Health Serv Res, 2011. **46**(4): p. 997-1021.
47. Riley, G.F., *Long-term trends in the concentration of Medicare spending.* Health Aff (Millwood), 2007. **26**(3): p. 808-16.
48. Robst, J., *Developing Models to Predict Persistent High-Cost Cases in Florida Medicaid.* Popul Health Manag, 2015. **18**(6): p. 467-76.
49. Rosella, L.C., et al., *High-cost health care users in Ontario, Canada: demographic, socio-economic, and health status characteristics.* BMC Health Serv Res, 2014. **14**: p. 532.
50. Snider, J.T., et al., *Identifying patients at risk for high medical costs and good candidates for obesity intervention.* Am J Health Promot, 2014. **28**(4): p. 218-27.
51. Tamang, S., et al., *Predicting patient 'cost blooms' in Denmark: a longitudinal population-based study.* BMJ Open, 2017. **7**(1): p. e011580.
52. Wammes, J.J.G., et al., *Characteristics and healthcare utilisation patterns of high-cost beneficiaries in the Netherlands: a cross-sectional claims database study.* BMJ Open, 2017. **7**(11): p. e017775.
53. Wodchis, W.P., P.C. Austin, and D.A. Henry, *A 3-year study of high-cost users of health care.* Cmaj, 2016. **188**(3): p. 182-8.
54. Zhao, Y., et al., *Identifying future high-cost cases through predictive modeling.* Disease Management and Health Outcomes, 2003. **11**(6): p. 389-397.
55. Zulman, D.M., et al., *Multimorbidity and healthcare utilisation among high-cost patients in the US Veterans Affairs Health Care System.* BMJ Open, 2015. **5**(4): p. e007771.

Reporting checklist for systematic review and meta-analysis.

Based on the PRISMA guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the PRISMA reporting guidelines, and cite them as:

Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement

		Reporting Item	Page Number
	#1	Identify the report as a systematic review, meta-analysis, or both.	1
Structured summary	#2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number	2
Rationale	#3	Describe the rationale for the review in the context of what is already known.	4
Objectives	#4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
Protocol and registration	#5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address) and, if available, provide registration information including the registration number.	-

Eligibility criteria	#6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rational	5,6
Information sources	#7	Describe all information sources in the search (e.g., databases with dates of coverage, contact with study authors to identify additional studies) and date last searched.	5
Search	#8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5 (appendix)
Study selection	#9	State the process for selecting studies (i.e., for screening, for determining eligibility, for inclusion in the systematic review, and, if applicable, for inclusion in the meta-analysis).	5,6
Data collection process	#10	Describe the method of data extraction from reports (e.g., piloted forms, independently by two reviewers) and any processes for obtaining and confirming data from investigators.	6,7
Data items	#11	List and define all variables for which data were sought (e.g., PICOS, funding sources), and any assumptions and simplifications made.	6
Risk of bias in individual studies	#12	Describe methods used for assessing risk of bias in individual studies (including specification of whether this was done at the study or outcome level, or both), and how this information is to be used in any data synthesis.	-
Summary measures	#13	State the principal summary measures (e.g., risk ratio, difference in means).	6,7
Planned methods of analyis	#14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I2) for each meta-analysis.	7
Risk of bias across studies	#15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	-
Additional analyses	#16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	7

Study selection	#17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	8
Study characteristics	#18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citation.	8,9
Risk of bias within studies	#19	Present data on risk of bias of each study and, if available, any outcome-level assessment (see Item 12).	-
Results of individual studies	#20	For all outcomes considered (benefits and harms), present, for each study: (a) simple summary data for each intervention group and (b) effect estimates and confidence intervals, ideally with a forest plot.	8-15
Synthesis of results	#21	Present the main results of the review. If meta-analyses are done, include for each, confidence intervals and measures of consistency.	8-15
Risk of bias across studies	#22	Present results of any assessment of risk of bias across studies (see Item 15).	-
Additional analysis	#23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	8-15
Summary of Evidence	#24	Summarize the main findings, including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., health care providers, users, and policy makers	15
Limitations	#25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review level (e.g., incomplete retrieval of identified research, reporting bias).	15
Conclusions	#26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	18
Funding	#27	Describe sources of funding or other support (e.g., supply of data) for the systematic review; role of funders for the systematic review.	19