Changes in the Air Ambulance Market and Effects on Individual Health Outcomes

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Abstract

Rising health care expenditures are fiscally concerning when they outpace the corresponding benefits of this spending. Air ambulance transport for trauma patients is a high-cost service that also has potentially high value. We use variation in reimbursements for air ambulance services generated by changes to Medicare's air ambulance fee schedule beginning in 2002 and data from a large trauma center to document a strong association between higher payment rates and growth in the air ambulance market. We find limited evidence of improved outcomes, and conclude that the benefits to patients may not outweigh the increased spending on these services.

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I. Introduction

As health care expenditures in the U.S. continue to rise, new high-cost technologies have been the subject of increased scrutiny. Diffusion of medical innovations has the potential to increase consumer welfare considerably, but the productivity of these innovations varies widely (Lakdawalla, Malani, and Reif 2017; Chandra and Skinner 2012). Technology that has both high fixed and high marginal costs may have particularly low value, as the benefits of these services have to be large and frequent to outweigh their costs.

Air ambulances are an example of one such high-cost innovation that has increased access to medical services for some patients. As a substitute for ground ambulance services, air ambulances give patients from remote areas direct access to specialized trauma services that are typically not available at local health care facilities, and provide a faster route in urban areas with congested routes to the hospital. Access to air ambulances has increased considerably in recent decades. Figure 1 shows that the number of rotor wing (helicopter) air ambulances in the U.S.[1], increased from 545 in 2003 to 1,461 in 2018. During this time, the share of the population that lived within a 20-minute response time for air ambulances increased from 70 percent to 86 percent (AAMS 2003; 2018). This access comes with a steep price tag, as air transport has both high fixed and high marginal costs. In 2010, while the median price of a ground ambulance was only \$429, for helicopter air transport it was \$15,000 and it rose to \$30,000 in 2014 (GAO 2012; GAO 2017). By 2016, Medicare expenditures for air ambulance services were \$246 million, up from \$25 million in 2001 (AAMS 2017). Given the acute nature of many traumatic injuries, greater and faster access to specialized trauma services could have large impacts on survival and long-term health.

Importantly, unlike many other commonly examined medical decisions, neither patients who have sustained a traumatic injury nor providers with a direct financial incentive in the mode of transport play a critical role in deciding how and to where a patient should be transported. At the scene of a traumatic event, emergency medical services (EMS) personnel (paramedics or emergency medical technicians) determine whether a patient should be transported to a health care facility, and whether transport should occur by ground or air ambulance. While EMS personnel do not have a direct financial stake in the decision of how to transport a patient, greater availability of air ambulances may lead to a greater likelihood of air transport. Because patients are not the primary decision makers in use of air ambulance services, out-of-network (surprise) billing is particularly pervasive in the air

[1] Rotor wing air ambulances are also referred to as helicopter emergency medical services (HEMS).

ambulance market (Cooper, Scott Morton, Shekita 2020). In 2017, approximately two thirds of air ambulances services billed to privately insured individuals were out-of-network (Chhabra et al. 2020; Bai et al. 2019; GAO 2019). One recent study found that out-of-network billing for air ambulance services at one national health insurer increased accounted for 71 percent of all billing for air ambulance services, from $41 million in 2013 to $143 million in 2017 (Chhabra et al. 2020). These billing practices are the focus of a class-action lawsuit against two for-profit air ambulance companies (Murphy v. Air Methods Corporation et al., 3:21-cv-10896).

Previous research has assessed the effect of air ambulance transport on health outcomes by comparing outcomes between patients transported by air to those of patients transported by ground ambulance. This approach could lead to biased estimates of the effect of air ambulance transport if patients transported by air are systematically different from patients transported by ground ambulance in ways that are not observable in the data. For example, if patients with more severe traumatic injuries are more likely to be transported via air and also more likely to have poor outcomes, this could lead to an underestimate of the beneficial effect of air ambulance transport. Alternatively, if patients with lower survival risk are less likely to be transported via air, this could lead to an overstatement of the effect of air ambulances. To address this potential bias, we exploit the timing of and geographic variation in the phased-in introduction of Medicare's ambulance fee schedule beginning in 2002 to estimate the effect of air ambulance transport on patient outcomes.

In an effort to spur growth in the supply of air ambulances, Medicare introduced an ambulance fee schedule beginning in 2002. This change resulted in higher reimbursements for air ambulance transports, phased in over 5 years, alongside an immediate 50 percent increase in reimbursements for transports originating in rural counties. Corresponding increases were not implemented for ground ambulance services. The tremendous growth in the air ambulance market between 2000 and 2010 closely paralleled implementation of Medicare's ambulance fee schedule and the associated large increases in payments to air ambulance operators, suggesting that this policy change had a substantial impact on the supply of air ambulances. We test whether the increased supply is associated with these fee increases.

Our primary data source is administrative records from a level I trauma center in Kentucky. Using these data, we first show that Medicare payment rate increases phased in from 2002 to 2005 led to increases both in the likelihood that a county has an air ambulance based in its county and the likelihood that a trauma patient arrives by air. These findings indicate a strong positive association between Medicare reimbursement rates for air ambulance services and air ambulance access. Next, we estimate the relationship between the increases in air ambulance access and patient outcomes, including hospital length of stay and likelihood of death. While the estimated coefficients on length of stay are negative, we find no statistically significant change for either health outcome considered. This is also the case even when we explore the heterogeneity of the effects by patient age and day of week. We extend our analysis to all inpatient hospitals in Kentucky, as well as inpatient stays from a broader range of states in the National Inpatient Sample. We find that our results are generalizable beyond a single trauma center.

To better understand the mechanism potentially driving these results, we examine whether there are compositional changes in patient type or transportation mode. We find that among all trauma cases, the average injury severity score of trauma patients (and, alternatively, the fraction arriving as mild, moderate, severe, or profound cases) is not statistically different after air ambulance access increases. However, when we look at the these separately by transportation type, we observe that the likelihood that mild injury cases are transported by air ambulance increases while the opposite is true for cases transported by ground ambulance. We then show that after air ambulance access increases, trauma transports to a hospital are more likely to be arriving directly from a scene. This is consistent with trauma patients being transported directly to a hospital with greater capacity to care for trauma patients, rather than being taken first to a local hospital for treatment before being transferred to a trauma center.

Our paper is among the first to examine the relationship between air ambulance market growth and patient outcomes. Our findings suggest that there were large increases in the supply of air ambulances in response to a change in the Medicare reimbursement schedule for emergency transport via helicopter air ambulance. However, we find little evidence that this improved patient outcomes as measured by hospital length of stay and mortality. We show that a larger fraction of trauma transports arrive directly from a trauma scene and that injuries among patients arriving via air ambulance are more likely to be mild when access to air ambulances increases. Taken together, this suggests that although patients appear to be getting to a trauma hospital more directly, this at best only modestly improves outcomes for the marginal patient. Air ambulances offer enormous potential for saving lives and improving outcomes among severely injured individuals. However, our findings suggest the increased costs associated with air ambulance transport are not offset by improvements in patient outcomes along the margins we consider, and call to question the value of increased availability of this service for many patients.

II. Background

Unintentional injury is a leading cause of death in the United States (Heron 2018) and has been cited as the leading cause of lost productive life years (American Association for the Surgery of Trauma 2019). The Centers for Disease Control estimates that total medical and lost productive costs associated with unintended injury in 2013 exceeded $670 billion (Florence, Haegerich, Simon, et al. 2015; Florence, Simon, Haegerich, et al. 2015). Efforts to improve health outcomes for patients with traumatic injuries have focused on developing and improving systems of care, designating trauma centers, and reducing the time from injury to arrival at definitive care. An integral part of all those efforts is reducing time from injury to arrival at a designated trauma center, including through the use of air ambulance transport.

When an individual experiences a traumatic injury, time is critical for a positive patient outcome. Proximity to a hospital is an important indicator of a positive patient outcome (Avdic 2016; Buchmueller, Jacobson, and Wold 2006; Bertoli and Grembi 2017). Minimizing the amount of time between a traumatic event and obtaining appropriate—in some cases, very intensive—care therefore has important implications for patient wellbeing (Wilde 2013). Before the advent of air travel, patients in critical condition were transported by ground ambulance to hospitals leading to potentially life costing delays in care. Today, patients experiencing a traumatic injury are commonly transported via air ambulance, which can be either a fixed wing airplanes or rotor wing (helicopters), where rotor wing aircraft now comprise more than 75 percent of U.S. air ambulances (Association of Air Medical Services 2018). Figure 1 plots the annual number of rotor wing aircraft from 1990 to 2017. This graph illustrates the dramatic growth in rotor wing aircraft since the early 2000s for the U.S. as a whole (left axis) and also for Kentucky (right axis), a state we will focus on in more detail in this study.

Trauma Triage

Trauma triage describes the decision regarding the level of care that should be provided to a trauma patient. Emergency medical service (EMS) personnel who arrive at a trauma scene determine whether and how patients are transported to a medical facility. Many factors go into this decision; we illustrate the flow of this decision in Appendix Figure 1. While an individual may choose to call 9-1-1 for ground ambulance services, a patient cannot directly request an air ambulance. When an individual experiences an injury and emergency services are requested, EMS personnel (paramedics or emergency medical technicians) are typically the first medical personnel to arrive, often via ground ambulance. The EMS personnel choose whether to treat a patient at the trauma scene, transport the patient to a local hospital for treatment, or transport a patient to a trauma hospital; they also determine whether patients should be transported by ground or air ambulance. Patients who are transported to local hospitals may later be transferred to a trauma hospital. Unlike some treatment decisions made by hospitals and physicians in fee-for-services settings, EMS personnel have no direct financial incentive to transport a patient via air ambulance.

Trauma triage for air transport is an imprecise process involving the patient's physiological condition, local hospital resources, distance and travel time to the trauma center, and provider intuition (Sasser, Hunt, Faul et al. 2011; Thomas, Brown, Oliver et al. 2014). It is common for such decisions to be made in high stress environments under both information and time constraints, which could lead to overtriage or undertriage. Whereas undertriage describes a situation where a provider may underestimate the degree of injury and provide too few resources to a patient, overtriage indicates that unnecessary resources were utilized in a trauma response (Cook et al. 2001). Criteria used to initiate air transport are not uniform, and reports of overtriage rates between 30 percent and 40 percent are common in the literature (Vercruysse et al. 2015; Brown et al. 2016a, 2016b; Chattopadhyay et al. 2018; Hakakian et al. 2019). Estimated overtriage rates are even higher for pediatric trauma transports (Michailidou et al. 2014; Fahy et al. 2018). The higher pre-hospital pediatric overtriage rates may be due to a number of factors including communication barriers due to the child's developmental stage, parent emotions, personal psychological stresses, and a lack of necessary skills to care for the injured child (Englum et al. 2017) Karutz and Wagner 2018). Rural hospitals in particular face an increasing shortage of surgical specialties and may lack resources to adequately evaluate and treat injured children (Thomas and Blumen 2018). The consequences of overtriage are not trivial as it indicates inefficient use of a scarce resource and generates higher spending (GAO 2017; Tozzi 2018; Rosato 2017; Saltzman 2016; Suiters 2016; Cates-Carney 2016). If increasing access to air transport increases the likelihood of overtriage, we expect more patients with mild injuries to be transported to a trauma center via air, and fewer via ground, when air ambulance supply increases. Alternatively, if it decreases undertriage, we expect increased air ambulance access will lead to improved health outcomes for the marginal trauma patient.

Ambulance Transport

There is a large medical literature on the effects of ambulance transport on patient outcomes, primarily focusing on ground ambulances. The economics literature is more limited but two recent studies, Doyle et al. (2015) and Doyle et al. (2017) show that ground ambulance companies are sensitive to market generated incentives and that these firm behavioral responses affect patient outcomes. Doyle et. al (2015) examines the relationship between the hospital a person is transported to and patient outcomes and finds that patients who go to higher cost hospitals experience better outcomes. They identify these effects using the assignment of ambulance to patients and the known pattern of ambulance companies being prone to transport to certain hospitals, as well as the strong Certificate of Need rules in New York, which assigns a territory to be served by a particular ambulance company. In short, they compare individuals on each side of the border since ambulances serving on each side are more likely to transport to their respective "preferred" hospital. In a follow-up study using the same data, Doyle et al. (2017) show that the one-year mortality is lower when patients go to higher cost hospitals and that this is driven by the lower likelihood of being served by a skilled nursing facility upon discharge after being treated by a lower cost hospital. We know of no literature in economics that has studied the air ambulance industry. This industry has experienced changes in the Medicare reimbursement schedule in the early 2000s that coincided with a sharp increase in the number of air ambulances, which may have affected patient outcomes.

Another strand of economic literature describes the relationship between insurance expansions under the Affordable Care Act (ACA), and ground ambulance utilization. These papers show that the number of ground ambulance dispatches for minor injuries increased after ACA implementation, suggesting that demand for ambulance services rose when the price to consumers dropped as a result of increased insurance coverage (Courtemanche et al. 2017; Courtemanche, Friedson, Rees 2018). Whereas the underlying mechanism in these studies is moral hazard—i.e., insurance reduces the price of health care services to consumers, and demand for health care rises when prices fall—in the context of the air ambulance market, consumers have little to no influence on the decision to airlift a patient, as we illustrate in Appendix Figure 1. Our focus on air ambulances is also unique because emergency medical personnel, who typically do not have a direct financial interest in a patient's mode of transport, are primarily responsible for making the decision about whether a patient should be transported by ground or air.

Medicare Reimbursement Policy Changes

Prior to 2002, the Centers for Medicare and Medicaid Services (CMS) payments for air ambulance services varied widely and were based on either reasonable costs or reasonable charges

(Health Care Financing Administration 2000). In an effort to spur growth in the air ambulance market and increase access to air ambulance services, CMS engaged in a negotiated rulemaking process that shifted reimbursement to a national fee schedule. Beginning in 2002, CMS phased in this fee schedule over 5 years. Air ambulance fee schedule payments consist of a base payment, geographic adjustment factor, and mileage to the nearest appropriate hospital (CMS 2002; GAO 2017). Furthermore, rural air ambulance transports received an additional 50 percent upwards adjustment for both the base payment and mileage (CMS 2004; CMS 2002; GAO 2017).[2] During this phase in period, the proportion of reimbursement based on reasonable costs decreased while the fee schedule proportion increased. Once completed, air ambulance reimbursement was solely based on the fee schedule (CMS 2002). Historic accounts of the policy change indicated considerable price increases for air ambulance carriers, of 200 percent to 400 percent (Abernethy 2014; Hawryluk 2014) and suggest that there was considerable growth in the supply of for-profit air ambulances in response to this price change (ConsumersUnion 2017; Perritt 2016). Since 2006, CMS has applied an inflation-based adjustment for air ambulance reimbursement (GAO, 2017; McKenna, 2015). Although the changes applied only to Medicare, and the largest proportion of patients transported by air ambulance are covered by private insurance, Medicare payment rates are often closely linked to payments made by private insurers (Cooper, Craig, Gaynor, and Van Reenan 2018; Clemens and Gottlieb 2017).

Figure 1 shows that growth the number of rotor wing air ambulances increased sharply during the phase-in period of the reimbursement changes. Figure 2 shows corresponding growth in allowed charges and services for ground, fixed wing, and rotor wing ambulances for Medicare beneficiaries between 2001 and 2010.[3] This figure demonstrates that growth for rotor wing air ambulances far outpaced that for the other types for both allowed charges (Panel A) and for allowed services (Panel B). Notably, the trends for rotor wing and fixed wing air ambulance services are very similar until the number of rotor wing flights began to increase steeply in 2003—the year after phase-in of the new air ambulance fee schedule began. Our empirical strategy, discussed in more detail below, uses changes in Medicare reimbursement for air ambulance services phased in from 2002 to 2006 to estimate the effect of increased air ambulance utilization on patient outcomes.

[2] CMS defined rural as outside of a Metropolitan Statistical Area or New England Statistical Area.
[3] Allowed charges include amounts paid by Medicare and the beneficiary.

III. Conceptual Framework

We discuss the EMS decision regarding mode of transportation for a trauma patient in the Background section. We more formally model the decision to transport via air ambulance (*A*) in the following equation:

$$A = f(C, G(\emptyset), \mathrm{J}(\omega)\, D(\delta), L(\theta), T(\gamma), M(\alpha)) \quad (1)$$

A medical personnel's decision about whether to transport a given patient by air depends on many factors. This decision foremost depends on how severely that patient is injured. We denote a patient's medical condition as C, and expect that an individual with a more severe medical condition will be more likely to be transported via air ambulance. First responders to the scene, often ground EMS (i.e., paramedics or emergency medical technicians), will have varying preferences about whether to treat a patient at the scene and, if transporting a patient to the hospital, whether to do so via ground or air ambulance. We denote these preferences as $G(\emptyset)$. The decision to transport via air ambulance may also account for patient preferences ($\mathrm{J}(\omega)$); however, we note individuals who are experiencing severe trauma may not have the capacity to refuse transport. Patient demographics, $D(\delta)$, also influence the likelihood of transportation, where δ measures age, race, gender, and type of insurance. Age in particular has been shown to be an important predictor of air ambulance transport, as children are more likely to be transported via air ambulance than adults (Michailidou et al. 2014; Fahy et al. 2018; Thomas and Blumen 2018). Local characteristics, $L(\theta)$, include distance to the nearest hospital, local hospital capacity (i.e., available beds as well as ability to treat trauma cases), and distance to the nearest trauma hospital. As local capacity rises (falls) we would be less (more) likely to observe transport via air ambulance. As transportation distance increases (decreases), to either a local or trauma hospital, we expect the likelihood of air transport to increase (decrease). Local capacity is in part a function of the time and day on which an event occurs—e.g., fewer physician specialists at a local hospital may be available on nights or weekends—which we include as a separate vector in our model. The time of the event ($T(\gamma)$) therefore indicates whether a trauma occurs during the day or night and on a weekday or a weekend. Last, other market factors, $M(\alpha)$, include the total number of rotor wing aircraft in service, composition of aircraft ownership (i.e., share of air ambulances owned by hospital versus a private company), and type of use (i.e., the share of aircraft that are used for other purposes in additional to emergency medical services).

In this paper, we focus on how the increased supply of air ambulances, encompassed by $M(\alpha)$, due to increased reimbursement rates for air ambulance flights changed the likelihood that a patient was transported via air ambulance, and whether that improved patient outcomes. As the supply of air ambulances in a market increases, we expect more patients to be flown by air ambulance. This is likely driven by the increase in the supply of air ambulances, since responding EMS personnel do not have a direct financial incentive when deciding whether the patient is flown by air ambulance. We also expect that, in particular, patients will be more likely to be transported directly to a trauma hospital when more air ambulances are available, and less likely to be transported first to a local hospital and then transferred to a trauma hospital. While any hospital transport could occur by ground or air ambulance, our focus is on air ambulance transports, as the incentive to transport patients via ground ambulance did not change considerably during our period of study.

IV. Data

Air Ambulance Supply

To estimate the relationship between reimbursement rates for air ambulance services and air ambulance supply, we need counts of the number of air ambulances licensed by county and state, over time. Rotor wing aircraft (helicopter emergency medical services, or HEMS) provide the vast majority of short distance air ambulance services in the U.S. (GAO, 2017); we therefore focus on rotor wing air ambulances in our analysis, though we note that some air ambulance services are provided by fixed wing aircraft. We compiled data for the number of U.S. rotor wing aircraft for 2003 through 2017 from the Atlas & Database of Air Medical Services (ADAMS). Prior to 2003, data on the number of HEMS in each state were not published by ADAMS. Data for the number of U.S. rotor wing aircraft in these earlier years were obtained from a 2010 Government Accountability Office report (GAO 2010), a 2009 National Transportation Safety Board presentation (Blumen 2009), and a 2014 report prepared by Economic & Planning Systems. We compiled data on the number of rotor wing aircraft for the state of Kentucky from the annual ADAMS data as well as through a Freedom of Information Act (FOIA) request to the Kentucky Board of Emergency Medical Services, the agency responsible for licensing all ambulances in Kentucky, including medical helicopters. Because we do not observe state- or county-level numbers of aircraft prior to 2003, we are limited to estimating the first stage supply effects of the Medicare reimbursement changes for the state of Kentucky.

Kentucky Trauma Center Data

Our primary data source for patient outcomes is case-level data from the University of Kentucky (UK) Trauma Center.[4] This data set contains information on the universe of patients treated by the University of Kentucky Hospital trauma program between 1990 and 2016. Extracted data include patient age, injury severity scores, and outcome data such as mortality, length of stay, and discharge disposition. The UK Trauma Center data provide information about patients who visited a level I trauma center, and allow us to directly consider the type of ambulance transport (i.e., ground or air). These data also identify a patient's county of pickup, so that we may exploit variation in reimbursement rates for rural areas before and after implementation of the Ambulance Fee Schedule in 2002. In an effort to create comparable samples between the trauma data and other data sets that cover a broader geographic area, described in Section IX, we include patients that arrived by both ground and air ambulance, and also consider these samples separately in our analyses. We focus on years 2000 to 2007 to capture the years during and shortly after implementation of the ambulance fee schedule.

The UK Trauma Center data are described in Table 1. Nearly 40 percent of trauma cases arrive at the hospital via air ambulance, almost half of which were transported directly from the trauma scene (i.e., not transferred from another hospital). Injury severity score (ISS) is a common means of classifying injury severity in trauma patients (Baker, O'Neill, Haddon, and Long 1974). The score is derived from anatomical injuries to any of nine body regions and ranges from 1 to 75. The ISS is also used to classify overall injury status as mild (1 to 8), moderate (9 to 15), severe (16 to 24), or profound (25 to 75). Although values for cut-offs are not without some controversy, the standard definition of severe trauma is an ISS of 16 or greater (Palmer 2007). The average ISS in the trauma center data is 17 for patients who arrived by air ambulance and 11.5 for patients transported by ground ambulance, indicating that injuries are more severe on average for patients who arrived by air. Likewise, patients who arrived via air are more likely to have injuries that are categorized as severe or profound, and appear to be slightly more likely to arrive on the weekend compared to those arriving via ground.

V. Methodology

Introduction of Ambulance Fee Schedule and County-Level Variation in Medicare Payment Rates

[4] We are grateful to the University of Kentucky HealthCare Trauma Program for providing these data.

Alongside the phase-in of the fee schedule described in the Background section, the ambulance fee schedule introduced a "rural add-on" which increased payments for transporting patients from rural areas.[5] Specifically, payments for any helicopter transport of a patient from a rural area on or after April 1, 2002 would receive a 50 percent increase in both the base rate and mileage. Using information on the county from which a patient was transported, we generate county-level payment rates by multiplying the adjusted air ambulance payment rates for Kentucky, described above, by 1.5 for rural counties beginning in 2002. Our analysis therefore exploits variation in payment rates across rural and non-rural counties and over time to estimate the impact of changes in reimbursement rates on air ambulance supply as well as the relationship between air ambulance utilization and patient outcomes.[6]

Implementation of Ambulance Fee Schedule and Air Ambulance Supply

Our empirical model attempts to identify the effect of increased transport via air ambulance on patient outcomes. We hypothesize that as reimbursement rates for air ambulance services increased, the number of air ambulances in each county increased. Because many counties in Kentucky have no air ambulances, we focus on an indicator for whether or not a county had any air ambulances. The administrative trauma center records include detailed information about how a patient was transported to the trauma center, including mode of transportation (ground or air) and whether the patient was brought directly from the scene or transferred from another hospital. Figure 3, which plots the number of patients transported by either ground or air on a log scale, illustrates the substantial relative growth in the number of patients arriving via air ambulance in the trauma center between 2002 and 2006, when Medicare payment rate increases were phased in.

We first consider the relationship between Medicare reimbursement rates for air ambulance services and whether a patient's county had at least one air ambulance using the state- and county-level variation described above.[7] The first stage equation below estimates the relationship between the natural log of Medicare payment rates and air ambulance availability:

[5] CMS defined rural as "located outside a Metropolitan Statistical Area (MSA), or a New England County Metropolitan Area (NECMA), or an area within an MSA that is identified as rural by the Goldsmith modification." (CMS, 2002). In the KY data we use the USDA's 2003 urban-rural continuum codes to specify metro (code = 1, 2, or 3) versus non-metro (code >3) based on the county where the patient's ambulance transport originated.

[6] The average payment change is different in each column of Table 1 because it is computed based on the county from which a patient was transported, and patient composition differs for ground and air ambulance samples.

[7] As we discuss in Section IV, for years prior to 2003 we only have the number and location of air ambulances for Kentucky, which we acquired using a FOIA request. For this reason, we only perform first stage regressions

$$y_{ilt} = \beta_0 + \beta_1 \ln(MedicarePmtRate_{lt}) + u_l + v_t + \epsilon_{ilt} \quad (2)$$

Our outcome of interest, y_{ilt}, is an indicator variable equal to one when the county where a patient is picked up has at least one air ambulance. As we discuss in the Section IV, for years prior to 2003 we only have the number and location of air ambulances for Kentucky, which we acquired using a FOIA request. For this reason, we are unable to extend our first stage analysis beyond this state. The variable $MedicarePmtRate_{lt}$ is the adjusted annual reimbursement rate in location l and time t. We observe patients at a single trauma center in a given year and the county from which a patient was transported. We therefore define location as county of pick-up and time as year, and include county and year fixed effects.[8]

Implementation of Ambulance Fee Schedule and Patient Outcomes

The increase in Medicare reimbursement rates for air ambulance services beginning in 2002 coincided with pronounced growth in the number of air ambulances in Kentucky and nationally, illustrated in Figure 1. We therefore use Medicare reimbursement rates for air ambulance services as an instrument for air ambulance availability to measure the effect of air ambulance transport on patient outcomes.[9] We focus on two measures of patient outcomes that are both costly and well established in the literature: hospital length of stay and mortality. We acknowledge that there are other important patient outcomes, but our data sets limit what we are able to examine. We conduct additional analyses to consider possible mechanisms as well as heterogeneity across patient and case characteristics.

VI. Results

We begin by examining whether the likelihood that a county has at least one air ambulance is positively correlated with Medicare reimbursement rates. We expect that as reimbursement amounts increase, more air ambulances will enter the market and therefore the likelihood that counties have at least one air ambulance will increase. We report results from our estimation of the relationship

[8] The Kentucky Hospital Inpatient Data, which we explore in Section IX, allows us to estimate a similar model. For these data, we define county fixed effects using a patient's county of residence. When we estimate a model for all Kentucky hospitals, we also include hospital and quarter of service fixed effects; these results are robust to including year rather than quarter fixed effects. For these models we generate payment rates using a patient's county of residence.
[9] We also estimate a reduced form model (results reported in Appendix Table 1), where we consider the relationship between Medicare payment rates and patient outcomes. For the reduced form, we adapt Equation (2) so that y_{ilt} measures either a patient's length of stay or whether the patient died in the hospital.

between Medicare payment rates for air ambulance flights and whether or not a county has at least one air ambulance in Table 2. The estimate reported in column 1 is calculated using the sample of all trauma patients of the UK Trauma Center over our sample period. This estimate indicates that when Medicare payment rates increase by 10 percent, the likelihood that a patient's county has at least one air ambulance increases by 0.019 (5.8 percent). All other estimates (patients transported by air (column 2), transported by ground (column 3), also indicate a strong positive relationship between Medicare's reimbursement levels for air ambulance services and the likelihood that a county has at least one air ambulance. In all cases, the F-statistics are well over 10 (in most cases over 100), alleviating concerns about weak instruments. Our results indicate that a 10 percent increase in Medicare reimbursements is associated with a 0.015 (4 percent) to 0.026 (8 percent) increase in the likelihood that a patient's county has at least one air ambulance, depending on the specification. We also note that the coefficients on patient injury severity score are all precisely estimated zeroes, indicating that there is no statistically significant correlation between patient injury level and the air ambulance supply. Our estimates show that as Medicare reimbursement rates rise, so does the availability of air ambulance.

Next, we examine whether the changes to reimbursements are associated with changes in patient outcomes. Table 3, similar in setup to Table 2, provides instrumental variables results when we instrument for the availability of air ambulance using the Medicare reimbursement rates and estimate two types of patient outcomes: hospital length of stay and in-hospital mortality. For in-hospital mortality, we also look separately at deaths that occurred within one day of hospital arrival, and those that occurred more than one day after hospital arrival.[10] Across all outcomes and samples, we observe no statistically significant change in patient outcomes associated with the reimbursement changes. We also estimate the reduced form relationship between the natural log of Medicare reimbursement rates for air ambulance services and two types of patient outcomes. Once again, no estimate is statistically significant. These estimates are reported in Appendix Table 1 (columns 1-3).

We explore heterogeneity within the UK trauma center IV results by considering whether there are differences in outcomes by age and day of the week (weekday or weekend) that a patient arrived at the hospital. Recall (from Table 1) that 16 percent of the trauma sample was under age 18, 74 percent was age 18 to 64, and 10 percent was age 65 and older. Additionally, 70 percent of UK trauma patients in our sample arrived on a weekday. We report IV heterogeneity results in Table 4.

[10] Individuals who are dead on arrival are excluded from the analysis sample.

All IV estimates of the relationship between air ambulance availability and patient outcomes are negative but statistically insignificant. In-hospital mortality results, however, are somewhat mixed. The only marginally statistically significant result is for patients under age 18, where greater air ambulance availability is associated with higher in-hospital mortality. However, the number of observations for this sample is relatively small and we are cautious in interpreting this result. We conclude that the findings for the full sample are perhaps driven by younger patients, but we do not have strong statistical confidence that there are differences in outcomes by day of the week.

VII. Robustness

Our main set of results measure the availability of air ambulances in a county using a binary indicator for whether the county the individual is transported from has an air ambulance. We use this measure for our main paper tables because we can use it for both the administrative trauma center data as well as the Kentucky Hospital Inpatient Data, which we describe in Section IX, making our results more comparable. Fortunately, we are able to use the administrative trauma center data to explore the robustness of our main results using a slightly different measure of availability of air ambulances. For each patient in the administrative trauma center data we have information on what mode of transport was used, which is not available in the inpatient data we explore later in this paper. We instrument for arrival by air using Medicare reimbursement rates and report these results in Table 5. Using this alternative measure of availability of air ambulance, we find a strong positive relationship between reimbursement rates and the likelihood that a patient arrived by air (column 1). However, as before, our instrumental variables estimates for patient outcomes indicate no statistically significant differences in hospital length of stay (column 2) or mortality (column 3). Last, unlike our preferred estimates, the first stage F-statistics, reported in the last row of the table, are all under 10.

VIII. Mechanisms

One possible factor in the estimated relationship between Medicare's reimbursement changes and the outcomes we have presented is that changes in the supply of air ambulances could change the composition of patients treated in level I trauma centers. Figure 4 shows the volume of cases by injury severity score (ISS) category for the UK Trauma data between 1994 and 2007. As described earlier, the ISS is a common means of classifying injury severity in trauma patients, derived from anatomical injuries to any of nine body regions and ranges. We observe sharp increases in volume after the 2002 policy change across all categories other than profound injuries, especially for patients who were transported by air.

Recall that, as reported in our first stage estimates in Table 2, we find that ISS is not a strong predictor for whether a county has an air ambulance. However, increased reimbursement for air ambulance services may lead to more pick-ups of patients with less severe injuries and it may increase the speed with which a trauma patient is picked up regardless of mode of transport. If this is the case, any observed differences in patient outcomes may reflect changes in the composition of patients transported by air ambulance rather than differences in the type and quality of care they receive. We use our IV model to examine this mechanism by including the patient's injury severity category (based on ISS score, described earlier) as the outcome in our model. Our findings, presented in Table 6, indicate that patients with mild and moderate injuries made up a greater share of trauma center transports as air ambulance availability increased. Conversely, those with severe injuries made up a smaller share of trauma center transports. There is also evidence of a shift in composition between air and ground ambulance transport, with mild cases more likely to be transported via air and less likely to be transported via ground.

Additionally, as reimbursement rates for air ambulance services increased, patients who might have otherwise been treated locally and then transferred to a hospital with greater capacity to care for trauma patients were more likely to be transported to a trauma center directly from the scene. Figure 5 shows that, prior to the Medicare change in fee schedule, the fraction of patients arriving directly from a scene via ground ambulance or air ambulance is similar. However, after the reimbursement began to be phased in beginning in 2002, the fraction of air ambulance arrivals coming directly from a scene increased dramatically, whereas for ground ambulance arrivals the trend was relatively flat. In Table 7, we estimate our IV model using administrative trauma center records, where our outcome is an indicator for whether or not a patient was directly transported from the trauma scene. Here we find a strong relationship between air ambulance access and patients being transported directly from the trauma scene, rather than being transferred from another hospital.[11] This is true for the full sample as well as the sample of arrival by air or arrival by ground. This suggests that air ambulance availability is decreasing the time to arrive at the trauma center for all modes of arrival.

[11] We acknowledge that some of these estimates are greater than one in this linear probability model. We opted for this specification because using fixed effects with nonlinear models leads to biased estimates, as discussed in Greene (2002).

These estimates suggest that air ambulance availability improves the speed with which trauma cases arrive at a trauma hospital and also shifts the composition to more moderate and mild cases. The ISS is assigned at the scene of the trauma. We would not expect that the availability of air ambulance changes the latent degree of trauma in an area. However, if the increased availability leads to quicker response time (either via ground or air) and that quicker arrival on the scene modestly changes the composition of patients' mode of transport, we would expect to see the patterns we do in Table 6. Specifically, we observe an increase in mild cases via air transport and a decrease in mild cases via ground transport.

IX. Validation with State and National Inpatient Data

Our analyses thus far are limited to a single trauma center using administrative data that may not be representative of other trauma centers and data which may not be available for other interested researchers. We validate our single trauma center results using more commonly available inpatient data. There are two key drawbacks to inpatient data. First, unlike the UK Trauma Center data, we do not observe mode of transportation and so we are unable to examine differences at this margin with the inpatient data. Second, as we describe below, we do not directly observe whether a patient is a trauma case, but rather use a proxy to identify cases that are likely trauma cases. With these caveats in mind, we replicate our main analysis using the subset of the inpatient data that is classified as a trauma case using our proxy. We start by doing so using data from the state of Kentucky and then we turn to a national inpatient dataset.

Kentucky Hospital Inpatient Data

To validate our findings obtained using the UK Trauma Center data, we first turn to the Kentucky Hospital Inpatient Discharge Database, which include data from the universe of hospital admissions from the state of Kentucky for 2000-2007. This database is maintained by the Kentucky Cabinet for Health and Family Services and includes records for all inpatient stays at Kentucky hospitals. The data do not specifically identify patients admitted to the hospital through a trauma center; we therefore create a proxy for trauma cases using information about the type of admission and International Classification of Diseases (ICD-9) diagnosis codes. To do so, we restrict our sample to admissions coded as urgent or emergent, which comprise 59 percent of admissions in our inpatient sample; this excludes elective and newborn admissions, which are unlikely to be related to trauma events. We further restrict our sample to cases defined as injuries in ICD-9 diagnosis codes, as defined by the State and Territorial Injury Prevention Directors Association and available through the Healthcare Cost and Utilization Project (HCUP).[12] ICD-9 injury codes have been used to identify trauma patients extensively in the trauma literature.[13] However, ICD-9 diagnosis codes are unknown at the time that decisions are made regarding whether and how to transport patients are made (Thomas and Blumen 2018). Using a proxy for trauma patients is not ideal, but is the only feasible way to identify trauma patients with this dataset. Specifically, hospital inpatient admissions data do capture 91 percent of trauma patients who are admitted through a trauma center (9 percent are not identified). However, patients who were actually admitted through a trauma center only represent 5 percent of the patients we identify as trauma patients using ICD-9 diagnosis codes as a proxy for trauma cases. Therefore, while our measure captures most patients who were admitted through a trauma center, the large majority of patients identified using our trauma proxy likely were not admitted through a trauma center, so we are misclassifying many non-trauma center patients as trauma patients using our proxy.

We summarize trauma cases in the Kentucky Hospital Inpatient Data for 2000 to 2007 in Table 8a. In column 1, we restrict these data to the University of Kentucky (UK) hospital, and in column 2, we show data for all Kentucky hospitals. Column 3 replicates summary statistics for the administrative (UK) trauma center data we examine in Table 1.[14] The average age of patients in our UK inpatient trauma sample is much older than in patients observed in the administrative data—for example, 17 percent of inpatients are over age 65, compared to only 10 percent of trauma center patients. We estimate that almost 90 percent of the UK inpatient trauma sample arrived "from scene" (did not arrive through a transfer from another hospital), compared to 40 percent of patients in the administrative trauma center data. Patients in the UK inpatient trauma sample had comparable lengths of stay on average, but lower mortality rates, than those in the administrative trauma center data. Injury severity scores were on average much lower for the UK inpatient trauma sample, and patients were much more likely to have mild injuries, than in the trauma center administrative case. Patients in our full inpatient trauma sample for Kentucky are on average older, have more mild injuries, and are much more likely to arrive directly from the scene when compared to patients observed in the administrative data.

[12] https://www.hcup-us.ahrq.gov/db/vars/siddistnote.jsp?var=injury.

[13] For example, see Myers et al. (2019), Akande et al. (2018), Kindermann et al. (2015), and Guice, Cassidy, and Oldham (2007).

[14] Due to data limitations on age for the Kentucky State Inpatient data, we adjust age groupings in our UK Trauma Center data to match those reported for the Kentucky State Inpatient data.

The estimated average Medicare payment change for patients in the administrative trauma center records is larger than the estimated payment change for patients in the inpatient trauma sample. The payment change is driven by payment changes for patients transported by air ambulance from rural counties, suggesting that rural patients are underrepresented in our inpatient trauma sample.

Using inpatient data we obtained directly from the state of Kentucky, we are able to observe a patient's county of residence. Using this information, we first replicate our UK Trauma Center analysis for patient data from UK Hospital, a sample that most closely matches what we observe for the UK Trauma Center data. Next, to test the generalizability of our findings, we extend our analysis to all hospitals in the state of Kentucky. The corresponding results are presented in Table 9 (first stage), Table 10 (patient outcomes from IV model), and Appendix Table 1 (patient outcomes from reduced form model). Our estimates continue to indicate a strong positive relationship between Medicare's reimbursement levels for air ambulance services and the likelihood that a county has at least one air ambulance, but no statistically significant change in patient outcomes associated with the reimbursement changes. Using inpatient data is not ideal in our setting given the potential misclassification of non-trauma patients as trauma patients and the lack of specificity for mode of transportation. However, the estimates for the state of Kentucky Inpatient data are similar to those we found with the UK Trauma Center data, and this reassures us that our findings are not limited to the particular administrative data we used.

National Inpatient Data

In this sub-section, we generalize our results by examining the impact of growth in the air ambulance market at the national-level. While we are not able to conduct as robust of an analysis nationally due to data limitations, we are able to examine whether the results presented for Kentucky likely apply more broadly to other states.[15] Below, we describe the cross-state variation as well as the national data set we utilize in this analysis.

[15] As we describe in Section V, we do not have data on air ambulance supply for all states prior to 2003 and we also do not have county identifiers in the NIS data.

State-Level Variation in Medicare Payment Rates

In addition to the fee bump for patients transported via air ambulance from rural counties, the introduction of the air ambulance fee schedule generated large increases in payment rates for all air ambulance services in some states between 2002 and 2006, as we describe in Section II. Over this period, CMS phased in the ambulance fee schedule, so payments were a weighted combination of the prevailing rates (reasonable charges or costs) and the fee schedule rate. The prevailing rates for air ambulance services varied widely across states, so the implementation of the fee schedule generated variation in reimbursement rates across states and over time, which we leverage in our national analysis. We focus on the prevailing inflation index charge (IIC) billed to independent suppliers of air ambulance services, which are available through the Ambulance Reasonable Charge Public Use Files.[16]

Payments are based on 2003 prevailing IIC and adjusted annually using the Ambulance Inflation Factor.[17] State-level payments are also adjusted to account for geographic variation in costs using the geographic practice cost index (GPCI).[18] Using these adjusted state-level prevailing IIC rates, we calculate the reimbursement rate for air ambulance services using the fee schedule phase-in:

$$\text{Medicare Payment Rate}_{st} = 0.2 * (2006 - \text{Year}_t) * \text{IIC}_{st} + 0.2 * (\text{Year}_t - 2001) * \text{AFS Rate}_t \quad (1)$$

Here, the Medicare payment rate for air ambulance services provided to a patient in state *s* and year *t* is a weighted combination of the geographically adjusted prevailing IIC in that state and year and the reimbursement rate from the ambulance fee schedule (AFS) in that year.

Appendix Figure 2 shows adjusted annual air ambulance payment rates by state and year for states that are included in the NIS for 2000 through 2007, and for whom data on prevailing IIC is available.[19] The figure indicates wide variation in base reimbursement rates for air ambulance services before the AFS was implemented, ranging from $758 in Utah to $3869 in Georgia. By 2006, base rates in all states are equivalent to the ambulance fee schedule value. Using NIS data, our

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[16] Ambulance Reasonable Charge Public Use Files are available at https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AmbulanceFeeSchedule/arcpuf.html. Reasonable charges are higher in some urban areas for four states in these data: California, Florida, Georgia, and Illinois. In these cases, we use the reasonable charge for non-urban areas, denoted as "rest of state".

[17] The Ambulance Inflation Factor (AIF) during this time period was equal to the projected Consumer Price Index for All Urban Consumers (CPI-U) minus one percentage point. CMS uses the AIF to update reimbursement rates annually for inflation. The payment rate shown for 2002 is based on the new fee schedule, which was implemented on April 1, 2002 (it therefore excludes payment rates for January through March of that year).

[18] CMS uses the GPCI to adjust the national fee schedule to reflect local costs.

[19] Reasonable charges are available for 15 of the 26 states in our NIS panel.

national analysis exploits this variation in Medicare reimbursement rates across states and over time to examine the relationship between air ambulance utilization and patient outcomes.

National (Nationwide) Inpatient Sample (NIS)

The National (Nationwide) Inpatient Sample (NIS), is part of the Healthcare Cost and Utilization Project (HCUP), through the Agency for Healthcare Research and Quality.[20] Similar to the Kentucky Hospital Inpatient data utilized in this study, the NIS contains information on patients and their hospital stays including basic demographic information (age, race, gender), diagnosis and treatment including length of stay and in-hospital mortality, as well as information about whether a patient was transferred from another hospital. For each hospital admission, we observe the state where the hospital is located. We restrict our sample to states for which data are available continuously between 2000 and 2007, and for whom we are able to identify prevailing air ambulance reimbursement rates prior to implementation of the ambulance fee schedule. Our sample ultimately includes 15 states; Appendix Table 2 provides the number of observations for each state in the NIS sample. We omit observations with missing information about source and type of inpatient admission, as well as patients that were discharged to another facility; the latter restriction helps to avoid double counting patients who were transferred to multiple facilities as the NIS does not include an identifier that allows us to track patients across multiple events.

Because we are unable to directly identify trauma patients in the NIS data, we create a proxy for trauma cases using the same procedure as that outlined for the Kentucky Hospital Inpatient data, above. Our final NIS sample consists of 1,212,970 emergent and urgent cases with ICD-9 injury codes. Summary statistics for the NIS data are provided in Table 8b. In this sample, 96 percent of cases were admitted directly from the scene, i.e., were not transferred from another hospital. The average length of hospital stay was 5.3 days, and just 2.8 percent of patients died in the hospital.

Similar to the Kentucky Hospital Inpatient records, the average age of patients in the national inpatient data is much older than that of patients observed in the administrative trauma center data. Patients in the national sample also had shorter lengths of stay, lower in-hospital mortality rates, and much lower injury severity scores than those in the trauma center data. If patients treated at the University of Kentucky Hospital trauma program are representative of other trauma centers in the U.S., the discrepancies between our samples suggests that even a national

[20] HCUP redesigned the Nationwide Inpatient Sample in 2012 and renamed it the National Inpatient Sample.

inpatient sample restricted to emergent and urgent cases with injury codes likely includes a number of non-trauma cases.

We estimate the reduced form empirical model from Equation (2) using the NIS data. Here, we define location at the hospital-level, and time as quarterly. For our national (NIS) analysis, we observe multiple hospitals and do not observe a patient's county of residence so we include hospital fixed effects in addition to quarter fixed effects controls.[21] In Table 11, we present reduced form results for the relationship between state-level payment rates for air ambulance services and patient outcomes (length of stay and in-hospital mortality) for the NIS sample. There is a statistically significant negative relationship between Medicare reimbursements for air ambulance services and length of stay, but a small and statistically insignificant relationship between reimbursements and mortality rates. Importantly, using state-level variation in reimbursement rates, we show that the reduced form estimates from the NIS are within the 95 percent confidence interval of the reduced form estimates from the Kentucky data presented in Appendix Table 1. Here, a 10 percent increase in Medicare reimbursements for air ambulance services is associated with a 0.15 (0.28 percent) decrease in hospital length of stay and no statistically significant change in mortality. While we do not have sufficient data on the number of air ambulances by state to estimate the first stage and IV relationships for a national sample between 2000 and 2007, our findings suggest that the observed relationships are not limited to one state.

X. Discussion and Conclusion

This paper examines the benefit relative to costs of high-cost innovation in health care, by examining the returns to increased investment in air ambulance services. Air ambulances may have large impacts on outcomes for patients who have experienced a traumatic injury by increasing their likelihood of quickly obtaining highly specialized medical treatment. However, the fixed and marginal costs of air ambulance services are high, necessitating large changes in patient outcomes to justify a broad increase in air ambulance services. Between 2002 and 2006, Medicare substantially increased reimbursement rates for transportation via helicopter air ambulance. Using administrative data from a trauma center, we find that the increase in Medicare reimbursement rates is associated with an increase in the supply of air ambulances in a county and the fraction of trauma cases that

[21] Because the new fee schedule was effective for claims with dates of service on or after April 1, 2002, we assign the prevailing Medicare rate for 2002 to the first quarter of that year.

arrive by air. Our estimates are consistent with the expansion of air ambulance supply improving patient outcomes as measured by length of stay, but this evidence is not statistically significant with the exception of a small decrease in length of stay estimated with the NIS data. For mortality, our estimates lack statistical significance. Consequently, we cannot infer that the increased resources allocated to air ambulances resulted in dramatic health improvements for these health outcomes. We do, however, find that trauma patients were more likely to arrive at a trauma center directly from the scene after the expansion, which may improve additional patient outcomes that are not available in our data sources. In particular, when we examine mode of transportation we find that the fraction of mild cases transported by air increases while the opposite occurs for ground. This suggests that increasing the supply of air ambulances led to a greater fraction of mild trauma cases transported via air.

One of the contributions of our study is that we use detailed administrative trauma center data, as well as inpatient data from a broader range of hospitals and states. While these three data sources are not directly comparable, they have relative strengths. The administrative trauma center data has detailed information on the location of a trauma event, mode of transport, and patient outcomes. However, these data are limited to trauma patients in a single hospital. The first inpatient sample includes a broader set of patients and hospitals within Kentucky. The second inpatient sample expands this to include hospitals outside of Kentucky. Both inpatient data sources include hospitals that are not necessarily level I trauma centers. Furthermore, including data from a national sample allows us to exploit variation in reimbursement changes across states to support our single state analysis.

Taken together, our estimates suggest that expansion of Medicare reimbursements for air ambulance services increases the availability and use of air ambulances. Increases in air ambulances in turn are at best weakly associated with decreases length of stay. Our estimates also show that these expansions increase the likelihood that trauma cases arrive directly at a trauma hospital and shift the classification of cases from more severe to less severe trauma. We would not expect the availability of air ambulance to change the underlying degree of trauma in an area. However, if the increased availability leads to quicker response time (either via ground or air) and that quicker arrival on the scene modestly alters the composition of patient transport, which is decided at the scene by the EMS, we would expect to see the patterns we do: a shift up in mild cases via air transport and a shift down in mild cases via ground transport and a possible decrease in the length of stay. While we do not have statistical confidence to infer effects on these health measures, the evidence we present does suggest patients may have benefited modestly, at least in terms of time spent in care.

Expanding air ambulance transport is quite expensive, and even though we estimate a small benefit of the expansion, in 2010, a year where we have both air (GAO, 2017) and ground costs (GAO, 2012) estimated, the reduction of LOS would have to have been nearly 8 days[22] to offset air transportation costing $14,500 more per flight than ground transportation; we note that the *mean* LOS in our air ambulance subsample is only 8.16 days. Furthermore, Delgado et al. (2013) finds that transport by air ambulance over ground should reduce mortality by 14 percent to be cost effective. We find no evidence of a mortality reduction due to increased utilization of air ambulances during the period we consider, a finding consistent with clinic research covering a more recent period (Al-Thani et al. 2017), but at odds with other clinical work (Galvagno et al. 2012; Galvagno et al. 2015). The additional benefit of air ambulance does not appear to justify its large price tag. One caveat of our findings is that we look at a limited set of patient outcomes; it could be that our data do not contain outcomes that would manifest large cost savings. Even so, our findings suggest that while health benefits of air transport exist, they may not outweigh the costs along the margins we consider.

[22] The average cost of a day of inpatient care in the United States in 2010 is $1,900. https://www.kff.org/health-costs/state-indicator/expenses-per-inpatient-day/?currentTimeframe=9&sortModel=%7B%22colId%22:%22Location%22,%22sort%22:%22asc%22%7D

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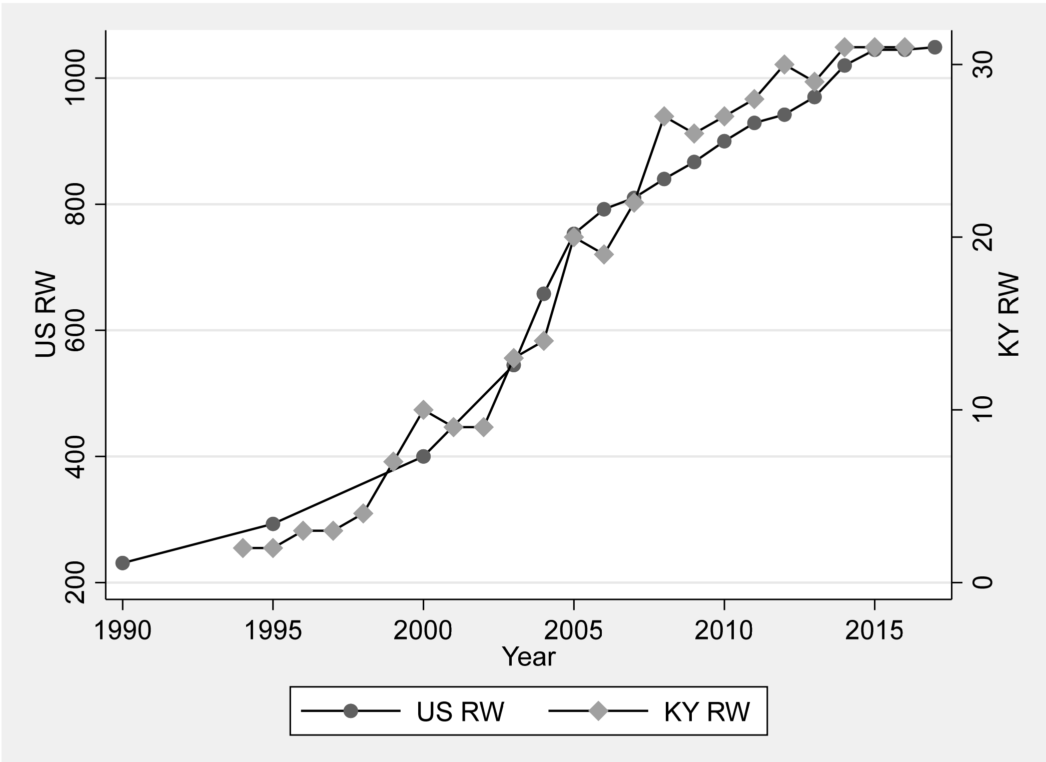
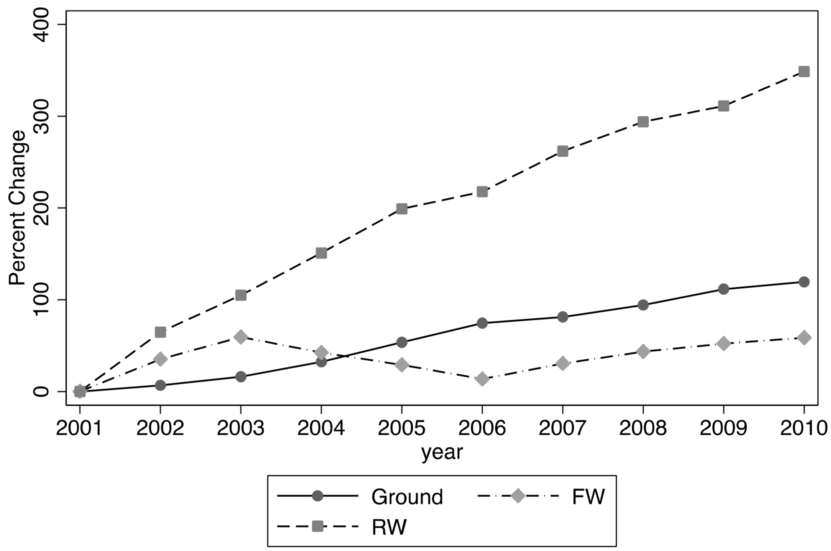
Figure 1: Total Helicopter Air Ambulances in U.S. and KY, 1990-2017

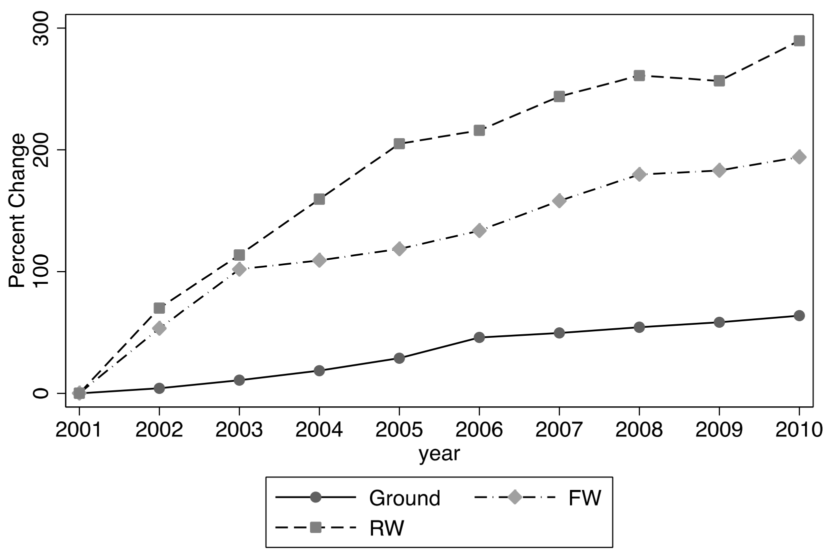


Source: Data for the number of US helicopter air ambulances for 2003 through 2017 were compiled from Atlas & Database of Air Medical Services (ADAMS). Data for US helicopter air ambulances prior to 2003 were obtained from a 2010 Government Accountability Office report (GAO 2010), a 2009 National Transportation Safety Board presentation (Blumen 2009), and a 2014 report prepared by Economic Planning Systems. Data for the number of helicopter air ambulances for the state of Kentucky were compiled from the annual ADAMS data and with a Freedom of Information request to the Kentucky Board of Emergency Medical Services (KBEMS), the agency responsible for licensing all ambulances in Kentucky, including medical helicopters.

Notes: The left vertical axis reports number of rotor wing used for air medical services in the United States while the right vertical axis reports this information for the state of KY.

Figure 2: Total Medicare Reimbursement and Services for Rotor Wing Aircraft, Fixed Wing Aircraft, and Ground Ambulances, 2000-2010

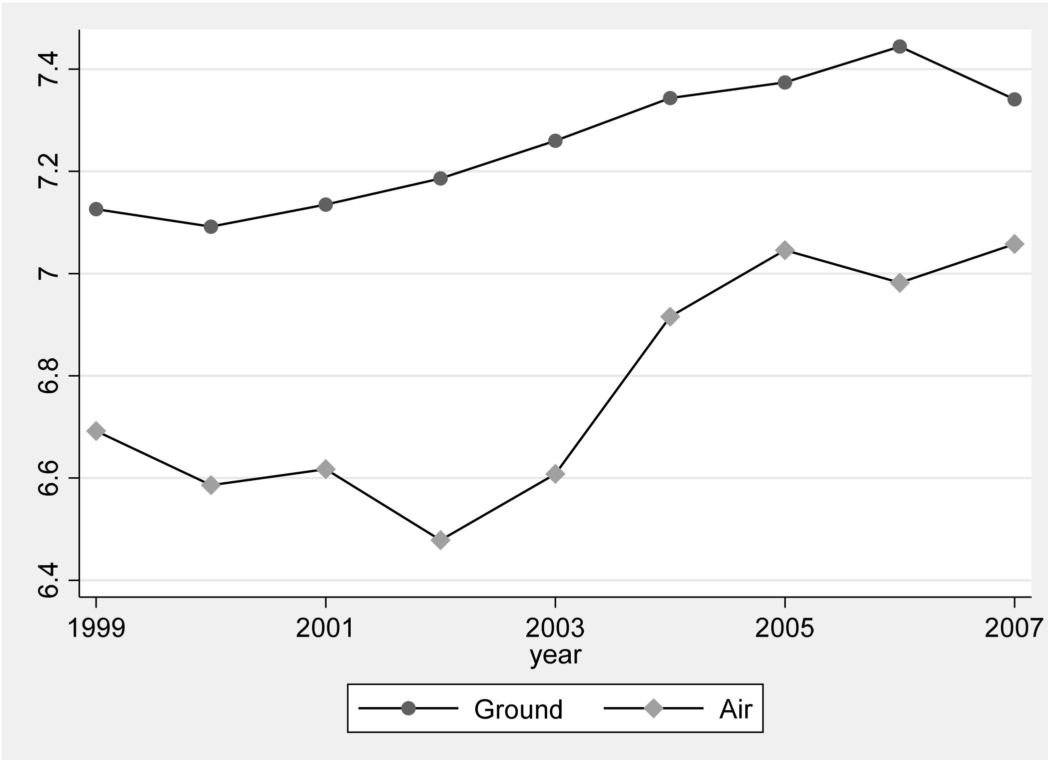




Source: Medicare National Part B Summary Files.

Note: Allowed charges include amounts paid by both Medicare and the beneficiary. Charges and services based on one-way transport, not including mileage. “RW” denotes rotor wing (i.e., helicopter), “FW” denotes fixed wing.

Figure 3: Trauma Cases (Log Values) by Admission Source, 1994-2007

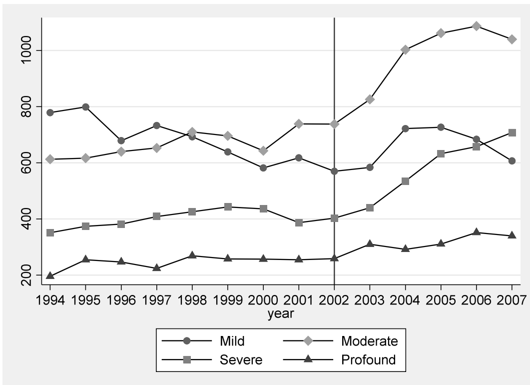


Source: University of Kentucky Trauma Center Medical Records.

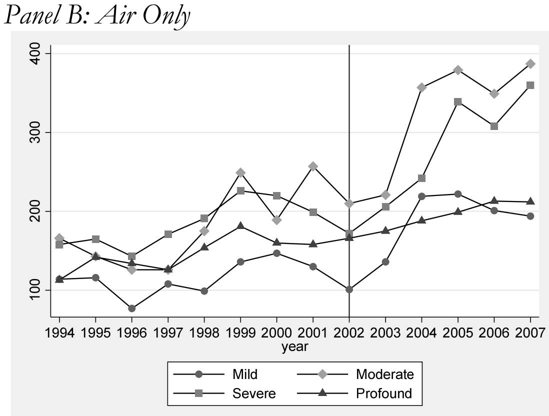
Notes: Each marker represents the log of the number of cases by transportation type in each year.

Figure 4: Injury Severity Composition of Trauma Patients Over Time

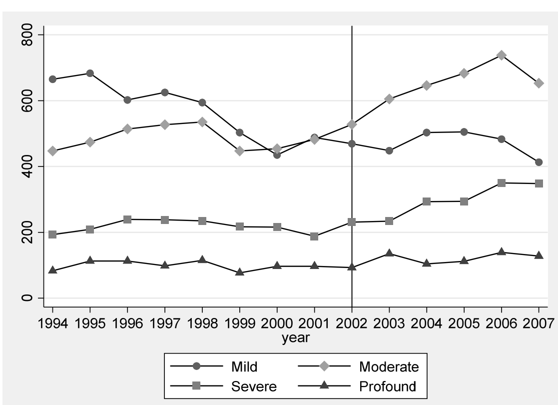
Panel A: Air & Ground



Panel B: Air Only



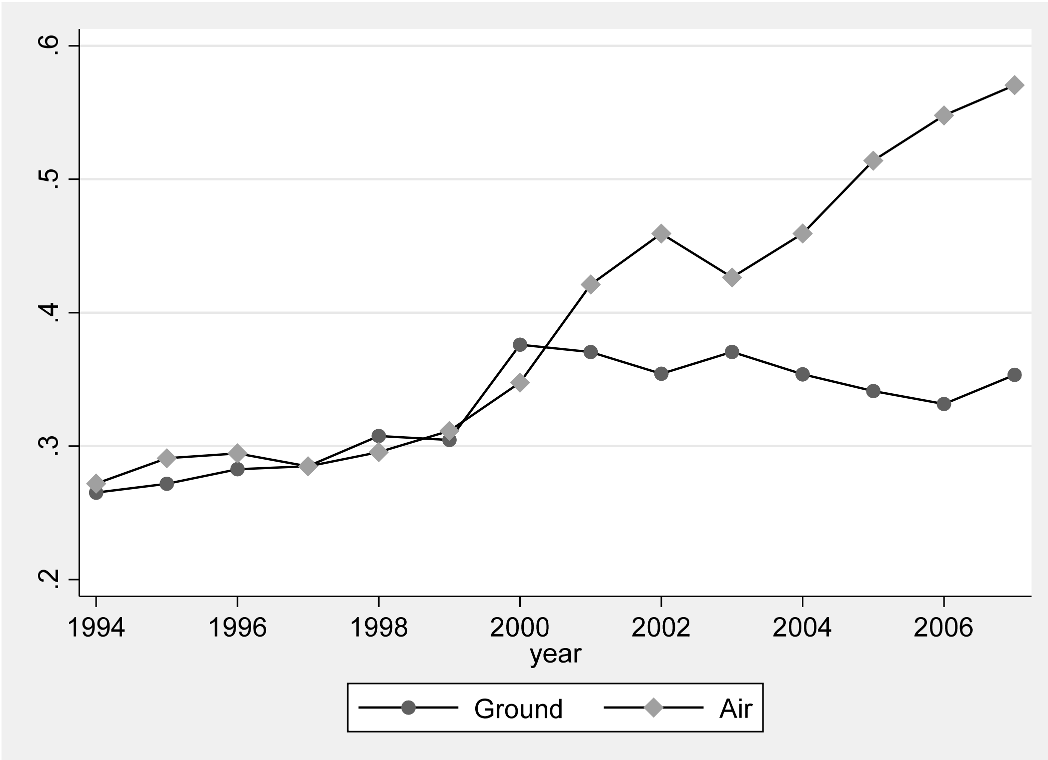
Panel C: Ground Only



Source: University of Kentucky Trauma Center administrative data, 1994-2007.

Notes: Injury severity score (ISS) is a common means of classifying injury severity in trauma patients, derived from classification of anatomical injuries to any of nine body regions; the score ranges from 1 to 75 (Baker, O'Neill, Haddon, and Long 1974). Injuries are categorized by ISS score as mild (8 or less), moderate (9 to 15), severe (16 to 24), or profound (25 or greater).

Figure 5: Share of Trauma Arrivals Directly from a Scene by Arrival Method, 1994-2007



Source: University of Kentucky Trauma Center administrative data. "Air" indicates helicopter emergency medical service (HEMS).

Table 1: Summary Statistics for Trauma Center Cases

Sample:	(1) All	(2) Air	(3) Ground
Age	36.32	36.08	36.48
Age <18	0.16	0.16	0.16
Age 18-64	0.74	0.74	0.73
Age 65+	0.10	0.10	0.11
From Scene	0.40	0.48	0.35
Died	0.06	0.10	0.04
Length of Stay	6.33	8.16	5.19
Injury Severity Score	13.65	17.01	11.53
Mild Injury (ISS≤8)	0.27	0.19	0.33
Moderate Injury (ISS 9-15)	0.38	0.33	0.41
Severe Injury (ISS 16-24)	0.22	0.28	0.18
Profound Injury (ISS 25+)	0.13	0.20	0.08
Weekday	0.70	0.66	0.73
Average Payment Change	$3,210	$3,519	$2,978
N	18,852	7,260	11,592

Source: University of Kentucky Trauma Center administrative data, 2000-2007.

Notes: “Air” (column 2) refers to arrivals by helicopter (rotor wing) aircraft. Data exclude patients that were dead on arrival. “From Scene” indicates that patient was not transferred from another hospital. Payer information is not available in the UK Trauma Center data. Average payment change is the difference in the mean payment rate between 2000 and 2007.

Table 2: First Stage Relationship Between Medicare Payment Rate and Air Ambulance Availability (At Least One Air Ambulance in County)

	(1)	(2)	(3)
Sample:	All	Air	Ground
Ln(Medicare Payment Rate)	0.194	0.151	0.174
	(0.0157)	(0.0378)	(0.0194)
Injury Severity Score	-0.000381	-0.000430	-0.000314
	(0.000153)	(0.000252)	(0.000188)
Mean of Dependent Variable	0.332	0.247	0.388
Observations	18,668	7,216	11,5452
Adjusted R-squared	0.810	0.716	0.853
First Stage F-Statistic	152.4	16.02	80.42
County of Pick-Up FE	Yes	Yes	Yes
County of Residence FE	No	No	No
Hospital FE	No	No	No

Source: University of Kentucky Trauma Center administrative data, 2000-2007.

Notes: We measure air ambulance availability as an indicator for whether there was an air ambulance in the county of pickup. "Air" (column 2) refers to arrivals by helicopter (rotor wing) aircraft. Data exclude patients that were dead on arrival. All regressions include year fixed effects.

Table 3: Instrumental Variables Results for Effect of Air Ambulance Availability on Patient Outcomes

	(1)	(2)	(3)
Sample:	All	Air	Ground
Panel A: Length of Stay			
Air Ambulance in County	-3.877	-32.35	0.806
	(4.659)	(21.91)	(5.442)
Injury Severity Score	0.325	0.304	0.303
	(0.0111)	(0.0193)	(0.0181)
Mean of Dependent Variable	6.332	8.163	5.186
Panel B: In-Hospital Mortality			
Air Ambulance in County	0.126	0.403	0.113
	(0.117)	(0.519)	(0.128)
Injury Severity Score	0.00929	0.00991	0.00822
	(0.000274)	(0.000475)	(0.000380)
Mean of Dependent Variable	0.0626	0.0979	0.0405
Panel C: Same Day In-Hospital Mortality			
Air Ambulance in County	0.109	0.442	0.0961
	(0.101)	(0.484)	(0.106)
Injury Severity Score	0.00597	0.00625	0.00538
	(0.000249)	(0.000432)	(0.000353)
Mean of Dependent Variable	0.0383	0.0605	0.0244
Panel D: >1Day In-Hospital Mortality			
Air Ambulance in County	0.0189	-0.0360	0.0175
	(0.0737)	(0.306)	(0.0843)
Injury Severity Score	0.00332	0.00365	0.00285
	(0.000200)	(0.000319)	(0.000283)
Mean of Dependent Variable	0.0244	0.0375	0.0161
Observations	18,642	7,198	11,435
First Stage F-Statistic	152	15.94	80.47

Source: University of Kentucky Trauma Center administrative data, 2000-2007.

Notes: "Air" (column 2) refers to arrivals by helicopter (rotor wing) aircraft. Data exclude patients that were dead on arrival. All regressions include year fixed effects. Robust standard errors are reported in parentheses.

Table 4: Heterogeneity of IV Results for Effect of Air Ambulance Availability on Patient Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
Sample:	All	Age<18	Age 18-64	Age 65+	Weekday	Weekend
Panel A: Length of Stay						
Air Ambulance in County	-3.877	-9.814	-2.370	-3.661	-3.201	-2.427
	(4.659)	(6.679)	(5.828)	(13.26)	(5.185)	(10.07)
Mean of Dependent Variable	6.332	4.330	6.471	8.471	6.422	6.120
Observations	18,642	2,980	13,715	1,935	13,119	5,509
First Stage F-Statistic	152	30.79	99.22	28.55	118.8	35.77
Panel B: In-Hospital Mortality						
Air Ambulance in County	0.126	0.437	0.0567	-0.0427	0.184	-0.105
	(0.117)	(0.261)	(0.131)	(0.417)	(0.132)	(0.237)
Mean of Dependent Variable	0.0626	0.0450	0.0512	0.171	0.0640	0.0594
Observations	18,650	2,980	13,721	1,937	13,126	5,519
First Stage F-Statistic	152.5	30.79	99.63	28.55	119.2	35.82

Source: University of Kentucky Trauma Center administrative data, 2000-2007.

Notes: Data include arrivals by both air and ground ambulance, and exclude patients that were dead on arrival. All regressions include year fixed effects. Robust standard errors are reported in parentheses.

Table 5: Effect of Air Ambulance Availability on Patient Outcomes, Instrumenting for Arrival by Air Ambulance

	First Stage	IV	
	Arrival by Air	*Length of Stay*	*In-Hospital Mortality*
Ln(Medicare Payment Rate)	0.0637		
	(0.0349)		
Arrival by Air		-11.90	0.384
		(16.01)	(0.407)
Injury Severity Score	0.0113	0.460	0.00490
	(0.000314)	(0.183)	(0.00460)
Mean of Dependent Variable	0.381	6.332	0.0626
Observations	18,668	18,642	18,650
First Stage F-Statistic	3.330	3.268	3.333

Source: University of Kentucky Trauma Center administrative data, 2000-2007.

Notes: Data include arrivals by both air and ground ambulance, and exclude patients that were dead on arrival. All regressions include year fixed effects. Robust standard errors are reported in parentheses.

Table 6: IV Results for Effect of Air Ambulance Availability on Patient Injury Severity

Sample:	(1) All	(2) Air	(3) Ground
Panel A: Injury Severity Score			
Air Ambulance in County	-0.674	-15.31	6.478
	(5.244)	(19.64)	(6.079)
Mean of Dependent Variable	13.65	17.02	11.53
Panel B: Mild Injury			
Air Ambulance in County	0.00442	1.230	-0.571
	(0.232)	(0.671)	(0.324)
Mean of Dependent Variable	0.273	0.187	0.327
Panel C: Moderate Injury			
Air Ambulance in County	-0.0217	-1.150	0.350
	(0.237)	(0.766)	(0.323)
Mean of Dependent Variable	0.380	0.326	0.413
Panel D: Severe Injury			
Air Ambulance in County	-0.147	-0.584	0.00797
	(0.196)	(0.711)	(0.248)
Mean of Dependent Variable	0.223	0.284	0.186
Panel E: Profound Injury			
Air Ambulance in County	0.204	0.504	0.264
	(0.167)	(0.701)	(0.185)
Mean of Dependent Variable	0.126	0.204	0.0781
Observations	18,650	7,202	11,439
First Stage F-Statistic	152.6	16.30	80.21

Source: University of Kentucky Trauma Center administrative data, 2000-2007.

Notes: "Air" (column 2) refers to arrivals by helicopter (rotor wing) aircraft. Data exclude patients that were dead on arrival. All regressions include year fixed effects.

Table 7: IV Results for Effect of Air Ambulance Availability on Direct Transport from Scene

	(1)	(2)	(3)
Sample:	All	Air	Ground
Air Ambulance in County	1.135	1.906	0.440
	(0.194)	(0.798)	(0.160)
Injury Severity Score	0.00654	0.00382	0.00188
	(0.000347)	(0.000751)	(0.000277)
Mean of Dependent Variable	0.403	0.480	0.355
Observations	18,650	7,202	11,439
First Stage F-Statistic	152.5	16.05	80.51

Source: University of Kentucky Trauma Center administrative data, 2000-2007.

Notes: "Air" (column 2) refers to arrivals by helicopter (rotor wing) aircraft. Data exclude patients that were dead on arrival. All regressions include county and year fixed effects. Robust standard errors are reported in parentheses.

Table 8a: Summary Statistics for Kentucky State Inpatient Data

Sample:	(1) UK Inpatient Trauma Sample	(2) Full Inpatient Trauma Sample	(3) UK Trauma Center
Age	-	-	36.32
Age <16	0.11	0.05	0.12
Age 16-20	0.10	0.04	0.12
Age 21-65	0.62	0.42	0.66
Age 66+	0.17	0.49	0.10
From Scene	0.89	0.97	0.40
Died	0.03	0.02	0.06
Length of Stay	6.32	5.54	6.33
Injury Severity Score	9.47	6.28	13.65
Mild Injury (ISS≤8)	0.44	0.61	0.27
Moderate Injury (ISS 9-15)	0.37	0.32	0.38
Severe Injury (ISS 16-24)	0.16	0.06	0.22
Profound Injury (ISS 25+)	0.04	0.01	0.13
Weekday	-	-	0.70
Average Payment Change	$2,324	$2,377	$3,210
N	12,972	182,662	18,852

Source: Kentucky Hospital Inpatient Discharge Database, 2000-2007, for columns 1 and 2. University of Kentucky Trauma Center administrative data, 2000-2007, for column 3.

Notes: Kentucky Hospital Inpatient Discharge Database data restricted to inpatient emergency and urgent cases with ICD-9 injury codes. "From Scene" indicates that patient was not transferred from another hospital. Only binned age data are available in the Kentucky Hospital Inpatient Discharge and Outpatient Services Databases. Average payment change is the difference in the mean payment rate for a sample between 2000 and 2007. Data include arrivals by both air and ground ambulance. See notes to Table 1 for column 3.

Table 8b: Summary Statistics for National (Nationwide) Inpatient Sample

Age	54.66
From Scene	0.9633
Died	0.0278
Length of Stay	5.3013
Injury Severity Score	5.3405
Weekday	0.7147
Primary Payer	
Medicare	0.4379
Private	0.2765
Medicaid	0.1123
Self-Pay	0.0961
Other	0.0772
Average Payment Change	$1,295
N	1,212,970

Source: National (Nationwide) Inpatient Sample (NIS), 2000-2007.

Notes: Data are restricted to emergency and urgent cases with ICD-9 injury codes; patients that were discharged to another hospital are excluded. Data include arrivals by both air and ground ambulance in all states for which NIS data are available in each year between 2000 and 2007.

Table 9: First Stage Relationship Between Medicare Payment Rate and Air Ambulance Availability (At Least One Air Ambulance in County), Kentucky Inpatient Data

	(1)	(2)
Sample:	UK Inpatient Trauma Sample	Full Inpatient Trauma Sample
Ln(Medicare Payment Rate)	0.1605	0.2635
	(0.0144)	(0.0047)
Injury Severity Score	-0.0003	0.0000
	(0.0002)	(0.0001)
Mean of Dependent Variable	0.304	0.337
Observations	12,972	182,662
Adjusted R-squared	0.8241	0.8307
First Stage F-Statistic	123.7	3105
County of Pick-Up FE	No	No
County of Residence FE	Yes	Yes
Hospital FE	No	Yes

Source: Kentucky Hospital Inpatient Discharge Database 2000-2007.

Notes: We measure air ambulance availability as an indicator for whether there was an air ambulance in the county of patient residence. Kentucky Hospital Inpatient Discharge Database data restricted to inpatient emergency and urgent cases with ICD-9 injury codes. Data include arrivals by both air and ground ambulance. All regressions include year fixed effects. Robust standard errors are reported in parentheses.

Table 10: Instrumental Variables Results for Effect of Air Ambulance Availability on Patient Outcomes, Kentucky Inpatient Data

	(1)	(2)
Sample:	UK Inpatient Trauma Sample	Full Inpatient Trauma Sample
Panel A: Length of Stay		
Air Ambulance in County	-6.7693	-1.0938
	(5.2103)	(0.7199)
Injury Severity Score	0.3081	0.2515
	(0.0151)	(0.0052)
Mean of Dependent Variable	6.323	5.545
Panel B: In-Hospital Mortality		
Air Ambulance in County	-0.0244	-0.0063
	(0.0982)	(0.0146)
Injury Severity Score	0.0050	0.0046
	(0.0004)	(0.0001)
Mean of Dependent Variable	0.0319	0.0243
Panel C: Same Day In-Hospital Mortality		
Air Ambulance in County	0.0064	-0.0008
	(0.0644)	(0.0075)
Injury Severity Score	0.0024	0.0022
	(0.0003)	(0.0001)
Mean of Dependent Variable	0.0127	0.00628
Panel D: >1Day In-Hospital Mortality		
Air Ambulance in County	-0.0308	-0.0055
	(0.0763)	(0.0127)
Injury Severity Score	0.0026	0.0024
	(0.0003)	(0.0001)
Mean of Dependent Variable	0.0192	0.0180
Observations	12,972	182,662
First Stage F-Statistic	123.7	3105

Source: Kentucky Hospital Inpatient Discharge Database, 2000-2007.

Notes: Air ambulance refers to helicopter (rotor wing) aircraft only. Kentucky Hospital Inpatient Discharge Database data restricted to inpatient emergency and urgent cases with ICD-9 injury codes. Data include arrivals by both air and ground ambulance. All regressions include year fixed effects. Robust standard errors are reported in parentheses.

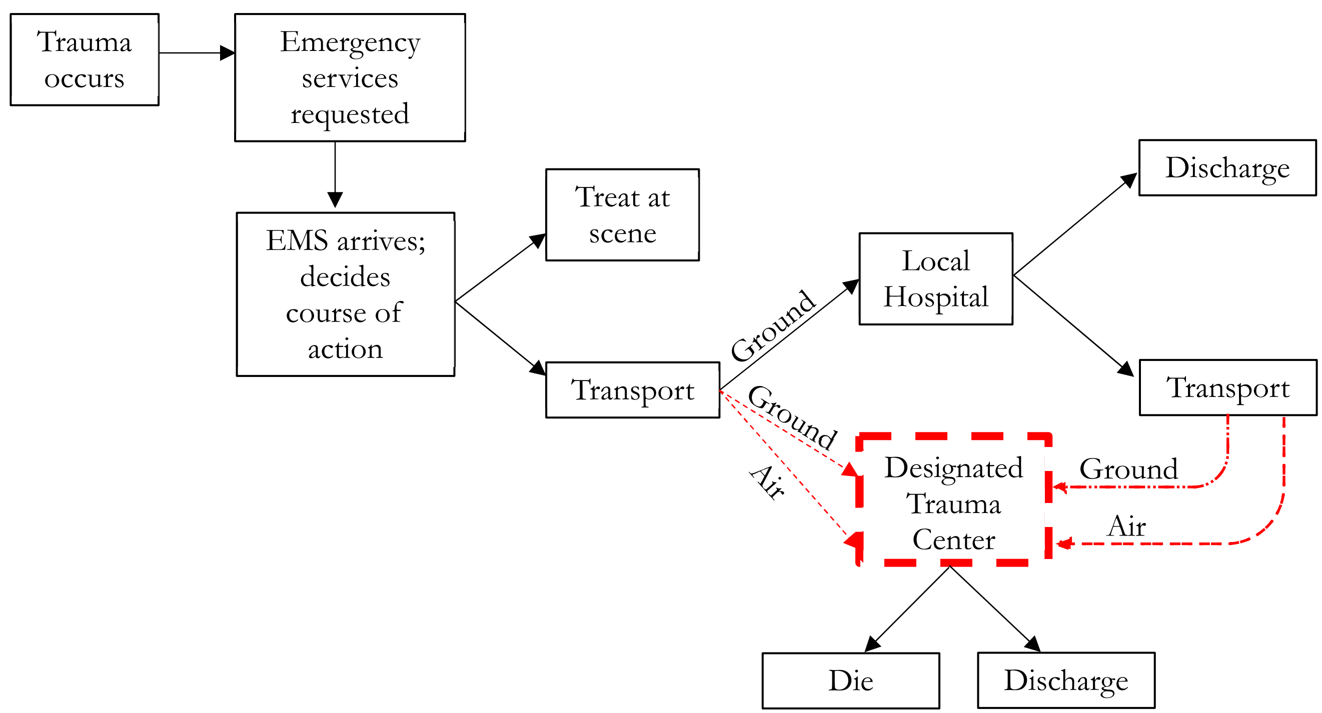
Table 11: Reduced Form Relationship Between Medicare Payment Rate and Patient Outcomes, National (Nationwide) Inpatient Sample

	(1)	(2)
Outcome:	*Length of Stay*	*In-Hospital Mortality*
Ln(State Medicare Payment Rate)	-0.1485	-0.0006
	(0.0556)	(0.0014)
Injury Severity Score	0.2872	0.0045
	(0.0021)	(0.0000)
Mean of Dependent Variable	5.3114	0.028
Observations	1,194,943	1,194,977

Source: National (Nationwide) Inpatient Sample (NIS), 2000-2007.

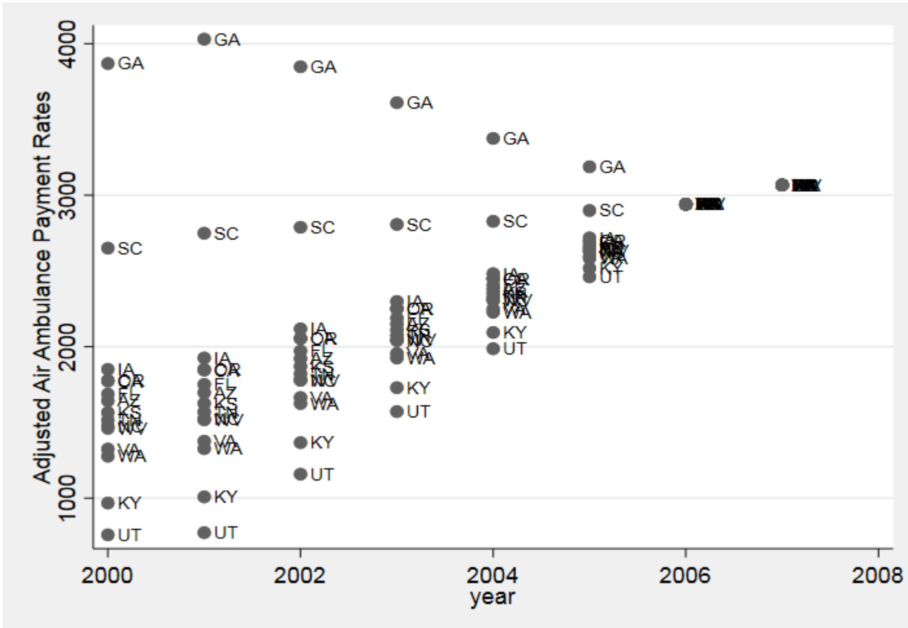
Notes: Data are restricted to emergency and urgent cases with ICD-9 injury codes; patients that were discharged to another hospital are excluded. Data include arrivals by both air and ground ambulance. NIS regressions are weighted by patient discharge weights and include hospital and quarterly fixed effects. Robust standard errors are reported in parentheses.

Appendix Figure 1. Trauma Triage Decision Tree



Source: Morris et a. (2021) and authors' conversations with an individual working as an air ambulance nurse in Kentucky during the period of study.

Appendix Figure 2: Medicare Payment Rate for Helicopter Emergency Medical Services, 2000-2007



Source: Ambulance Fee Schedule and Ambulance Reasonable Charge Public Use Files.

Note: Medicare payment rate for air ambulance services is a weighted combination of the geographically adjusted prevailing inflation indexed charge in that state and year and the reimbursement rate for one-way rotary wing transport (not including mileage) from the Medicare Ambulance Fee Schedule (AFS) in that year (https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AmbulanceFeeSchedule/). Payments are based on the 2003 prevailing IIC, obtained from the Ambulance Reasonable Charge Public Use Files (https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AmbulanceFeeSchedule/arcpuf.html) and adjusted annually using the Ambulance Inflation Factor. State-level ambulance payments are adjusted to account for geographic variation in costs using the geographic practice cost index.

Appendix Table 1: Reduced Form Relationship Between Medicare Payment Rate and Patient Outcomes

Data Source:	University of Kentucky (UK) Trauma Center			Kentucky Inpatient Data	
Sample:	*All*	*Air*	*Ground*	*UK Inpatient Trauma Sample*	*Full Inpatient Trauma Sample*
Panel A: Length of Stay					
Ln(Medicare Payment Rate)	-0.751	-4.879	0.140	-1.0864	-0.2883
	(0.902)	(3.124)	(0.949)	(0.8331)	(0.1897)
Injury Severity Score	0.326	0.317	0.303	0.3103	0.2514
	(0.0112)	(0.0144)	(0.0184)	(0.0150)	(0.0052)
Mean of Dependent Variable	6.332	8.163	5.186	6.323	5.545
Observations	18,660	7,212	11,448	12,972	182,662
Adjusted R-squared	0.108	0.093	0.093	0.0921	0.0334
Panel B: In-Hospital Mortality					
Ln(Medicare Payment Rate)	0.0245	0.0611	0.0196	-0.0039	-0.0017
	(0.0226)	(0.0772)	(0.0222)	(0.0158)	(0.0039)
Injury Severity Score	0.00924	0.00973	0.00819	0.0050	0.0046
	(0.000270)	(0.000402)	(0.000377)	(0.0004)	(0.0001)
Mean of Dependent Variable	0.0626	0.0979	0.0405	0.0319	0.0243
Observations	18,668	7,216	11,452	12,972	182,648
Adjusted R-squared	0.153	0.144	0.147	0.0419	0.0245
Panel C: Same Day In-Hospital Mortality					
Ln(Medicare Payment Rate)	0.0210	0.0667	0.0167	0.0010	-0.0002
	(0.0196)	(0.0707)	(0.0184)	(0.0104)	(0.0020)
Injury Severity Score	0.00593	0.00607	0.00535	0.0024	0.0022
	(0.000244)	(0.000354)	(0.000350)	(0.0003)	(0.0001)
Mean of Dependent Variable	0.0383	0.0605	0.0244	0.0127	0.00628
Observations	18,660	7,212	11,448	12,972	182,662
Adjusted R-squared	0.103	0.092	0.107	0.0253	0.0204
Panel D: >1Day In-Hospital Mortality					
Ln(Medicare Payment Rate)	0.00366	-0.00544	0.00305	-0.0049	-0.0015
	(0.0143)	(0.0461)	(0.0147)	(0.0123)	(0.0034)
Injury Severity Score	0.00331	0.00367	0.00284	0.0026	0.0024
	(0.000199)	(0.000294)	(0.000283)	(0.0003)	(0.0001)
Mean of Dependent Variable	0.0244	0.0375	0.0161	0.0192	0.0180
Observations	18,660	7,212	11,448	12,972	182,662
Adjusted R-squared	0.050	0.046	0.046	0.0175	0.0093

Source: University of Kentucky Trauma Center administrative data (columns 1-3) and Kentucky Hospital Inpatient Discharge Database (columns 4-5), 2000-2007.

Notes: UK Trauma Center data exclude patients that were dead on arrival. Kentucky Hospital Inpatient Discharge Database data restricted to inpatient emergency and urgent cases with ICD-9 injury codes. Kentucky Inpatient Data include arrivals by both air and ground ambulance. All regressions include year fixed effects. Robust standard errors are reported in parentheses.

Appendix Table 2: States included in National Panel

State	Number of Observations
Arizona	65,789
Florida	356,305
Georgia	112,351
Iowa	54,544
Kansas	45,389
Kentucky	72,011
North Carolina	145,631
Oregon	46,528
South Carolina	51,364
Tennessee	110,072
Utah	28,072
Virginia	85,739
Washington	54,969
West Virginia	34,182
Total	1,262,946

Source: National (Nationwide) Inpatient Sample, 2000-2007.

Notes: Data restricted to emergency and urgent cases with ICD-9 injury codes; patients that were discharged to another hospital are excluded. Sample includes states that were included the NIS for all years between 2000 and 2007, for whom air ambulance payment rates are available through the Ambulance Reasonable Charge Public Use Files (https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AmbulanceFeeSchedule/arcpuf.html). Data are not weighted, and include arrivals by both air and ground ambulance.