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Reconstructive

Use of Flap Salvage for Lower Extremity Chronic Wounds Occurs Most Often in Competitive Hospital Markets

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Background: Wounds in the comorbid population require limb salvage to prevent amputation. Extensive health economics literature demonstrates that hospital activities are influenced by level of market concentration. The impact of competition and market concentration on limb salvage remains to be determined.
Methods: Admissions for chronic lower extremity wounds in nonrural hospitals were identified in the 2010–2011 National Inpatient Survey using ICD-9-CM diagnosis codes. The study cohort consisted of admitted patients receiving amputations, salvage without flap techniques (eg, skin grafts), or salvage with flap techniques. The all-service Herfindahl–Hirschman Index (HHI), which is a commonly used tool for market and antitrust analyses, was used to measure hospital competition. Multinomial regression analysis accounting for the complex survey design of the NIS was used to determine the relationship between the HHI and hospital adoption of limb salvage controlling for patient, hospital, and market factors.
Results: The study cohort represents 124,836 admissions nationally: 89,880 amputations, 26,715 salvage without flap techniques, and 8241 salvage flap techniques. Diabetics accounted for 64.1% of all study admissions. Hospitals in highly competitive markets performed more flaps for chronic lower extremity wounds than noncompetitive markets. Controlling for other factors, hospitals in highly competitive markets, relative to those in highly concentrated markets, were 2.48 percentage points more likely to perform limb salvage with flaps ($P < 0.01$). Other factors were less predictive.
Conclusion: Increased hospital competition is the strongest systems-level predictor of receipt of lower extremity flaps among patients with chronic wounds. Improving access to reconstructive limb services must consider the competitive structure of hospital markets. *(Plast Reconstr Surg Glob Open 2021;9:e3183; doi: 10.1097/GOX.0000000000003183; Published online 12 February 2021.)*

INTRODUCTION

Lower extremity amputation due to a chronic wound is a preventable consequence of peripheral vascular disease and diabetes.[1] In the diabetic population, a new onset diabetic foot ulcer has an associated mortality rate between 43% and 55% and rises to 75% after amputation.[2–4] When amputation occurs, data suggest that there is an exacerbation of existing comorbidities, rather than a new disease process, which results in increased mortality.[5] Prevention of amputation is possible when a multidisciplinary approach is utilized. With aggressive wound coverage by plastic surgeons and revascularization with vascular surgery, amputations can be avoided in up to 50% of cases, leading to cost, quality of life, and mortality benefits.[6–11] These modalities, including skin grafts, local flaps, and free flaps, can lead to limb salvage and ambulation rates of up to 83.5% and 92.7%, respectively.[12] Oh et al[13] demonstrated a 5-year mortality benefit in matched patients receiving free flaps versus amputation (86.8% vs 41.4%).

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Despite the documented benefit of limb salvage procedures, these services remain highly underutilized.

Additionally, significant disparities in access to limb salvage modalities exist for patient-level and hospital-level factors. In particular, being white non-Hispanic and receiving treatment in urban teaching hospitals were the strongest protective factors against amputation and predicted receipt of advanced limb salvage modalities.[14] In light of these results, a significant question of patient biology and factors versus the treatment environment can be posited.[15] Studies suggest a regional bias in the use of amputation versus salvage.[16–18] There is strong geographical clustering and varying rates of use of the lower extremity amputation, suggesting location of care heavily influences receipt of surgical treatment.[16] Furthermore, there is a growing body of the literature suggesting that market forces significantly impact the adoption and delivery of advance surgical care.[19–22]

In light of this published literature, it is clearly plausible that market forces among hospitals may influence delivery of limb salvage modalities. These modalities require significant investments in infrastructure and coordination of multidisciplinary medical teams. We hypothesize that the incentives to invest in these modalities are stronger for hospitals in more competitive markets where there is a credible threat of losing patients to other facilities. Conversely, hospitals in less competitive markets are under less pressure to quickly invest in the latest care innovations and can more easily limit care in saturated service lines without fear of patients going to competitors. This hypothesis, however, has never been tested empirically in the case of limb salvage. We sought to fill this gap with an analysis of the Nationwide Inpatient Sample (NIS) from 2010 to 2011 linked with the hospital market structure (HMS) database. In this study, we hypothesized that increased hospital competition and decreased market concentration will lead to augmented use of advanced lower extremity salvage modalities.

METHODS

Cohort Selection

As part of the Healthcare Cost and Utilization Project sponsored by the Agency for Healthcare Research and Quality (AHRQ), the NIS is the largest publicly available all-payer administrative databases representing hospital admissions nationwide, sampling 7 million inpatient hospital stays and discharges per year. We used data from 2010 to 2011, where the AHRQ provided additional HMS files. The 2009 HMS file was linked to the NIS database for the years of interest, and unlinked hospitals were eliminated from the analysis.[29]

ICD-9-CM codes were used to identify admissions for lower extremity wounds (707.06, 707.07, 707.1x, 707.8, and 707.9) based on a previously described methods to capture all relevant admissions.[23,24] ICD-9-CM procedure codes were used to identify patients receiving major amputations (excluding toe amputations) (84.12–84.17), limb salvage techniques without flap reconstruction (eg, skin graft or allograft) (86.6, 86.60, 86.63, 86.65–86.67, 86.69, 86.89, 86.91, and 86.99), and advanced limb salvage with flap reconstructive techniques (eg, free flap, pedicle flap, revision of flap, and inset of flap) (86.7 and 86.70–86.75).[25] Patients with lower extremity wounds without procedure codes of interest were excluded. Vascular intervention within the same hospital stay were identified.[26] Vascular procedures were stratified as open (39.25, 39.29, 38.08, 38.18, 38.38, 38.48, 38.68, and 38.88) and endovascular (39.40 and 39.90).[27]

Measure of Competition

Our key independent variable is hospital market concentration as measured by the Herfindahl–Hirschman Index (HHI) for all hospital discharges. The HHI is defined as the sum of the squares of the market shares for all hospitals in a market area. In the NIS-HMS database, the market area is defined for each hospital as the smallest set of zip codes that account for at least 90% of discharges (known as the 90% variable radius method). The HHI ranges from 0 (indicating a highly dispersed or competitive market) to 10,000 (indicating a pure monopoly market).[28] For antitrust litigation purposes, the US Department of Justice classifies markets using the following standards: HHI <1500 indicates an unconcentrated/competitive market, 1500–2500 indicates moderately concentrated, and >2500 indicates highly concentrated/noncompetitive.

In the HMS, market may be defined based on patient flow, geopolitical boundaries, fixed radius, or variable radius.[30] Based on sensitivity analysis, a variable radius that captures 90% of the hospital's discharge was selected as the market, over patient flow (the collection of zip codes that send a nontrivial amount of patients to a hospital), geopolitical boundaries (metropolitan statistical areas, health service areas, and core-based statistical areas), fixed radius (a region enclosed by a circle within a 15-mile radius), and other variable radius (75% a variable radius that captures of hospital's discharge). Variable radius also considers the fact that hospitals do not compete within a fixed geographical area.[20] In rural areas, populations are too sparse to support competitive hospital markets, making most rural markets highly concentrated. Therefore, rural hospitals are excluded from this analysis.[31] Hospitals with incomplete data in the HMS file were also excluded.

Outcome Measures and Predictors

Receipt of amputation, limb salvage techniques without flap reconstruction, and advanced limb salvage techniques with flap reconstruction were the primary outcomes. The key predictors include HHI with a variable radius capturing 90% of the hospital's discharge, patient factors (age, sex, race, median household income, insurance, urban versus rural residence, and Elixhauser comorbidity index), and hospital factors (number of beds, teaching status, and region). Individuals were excluded if they had insurance that could not be classified as private, Medicare, Medicaid, or self-pay (a proxy for uninsured status) due to small sample size. Additional comorbidities included in the analysis were as follows: end-stage renal disease (ESRD) (585.4), diabetes (250.xx), previous history of amputation (V497.x), history of smoking

(v152.82, 305.1), peripheral vascular disease (440.x, 441.x, and 443.9 250.71–270.73), and lower extremity infection (680.6, 680.7, 682.6 682.7, 730.6, 730.07, 730.16, 730.17, 730.26, 730.27, 730.96, 730.97, and 785.4).[32] Cases with gas gangrene (040.0), children, and pregnant women were excluded from the study because reconstructive algorithms are different in this population.

Statistical Analysis

Statistical analysis was performed using the "svy" command in STATA 16.0 (StataCorp, College Station, Tex.) to account for the complex survey design of the NIS. We used 2-way Chi-square tests to determine whether patient and hospital characteristics influenced the 3-level study outcome. Multinomial logit and probit regression methods were used to assess the independent contributions of each variable to the likelihood of having 1 of the 3-level outcomes.[33] Although amputation is clearly inferior to limb salvage, the ranking of reconstruction depends on factors (eg, wound severity and location) that are not measurable, precluding the use of an ordered model. The Hausman test may be used outside the complex survey environment but is unavailable in this setting. We estimated both logit and probit models and found results to be identical. The data from the multinomial probit model are provided, given there are more robust underlying assumptions about the data: specifically the assumption of independence of irrelevant alternatives, which cannot be verified for the multinomial logit model without the Hausman test.

We present findings in terms of marginal effects, which show how each independent variable affects the probability that a patient experiences any of the 3 outcomes in percentage points (PPs), holding the other independent variables fixed. Statistical significance was set at $P < 0.05$. As this is a large database, effect sizes were emphasized over statistical significance.

RESULTS

The study cohort included 25,415 patients representing 124,836 discharges: 89,880 amputations (72.0%), 26,715 lower extremity salvage without flaps (21.4%), 8241 advanced lower extremity salvage with flaps (6.6%) (Fig. 1). Of these patients, 65.1% were diabetic, 17.1% had ESRD, and 58.0% had peripheral vascular disease. The majority of cases were performed in hospitals operating in unconcentrated/competitive markets (59.2%), followed

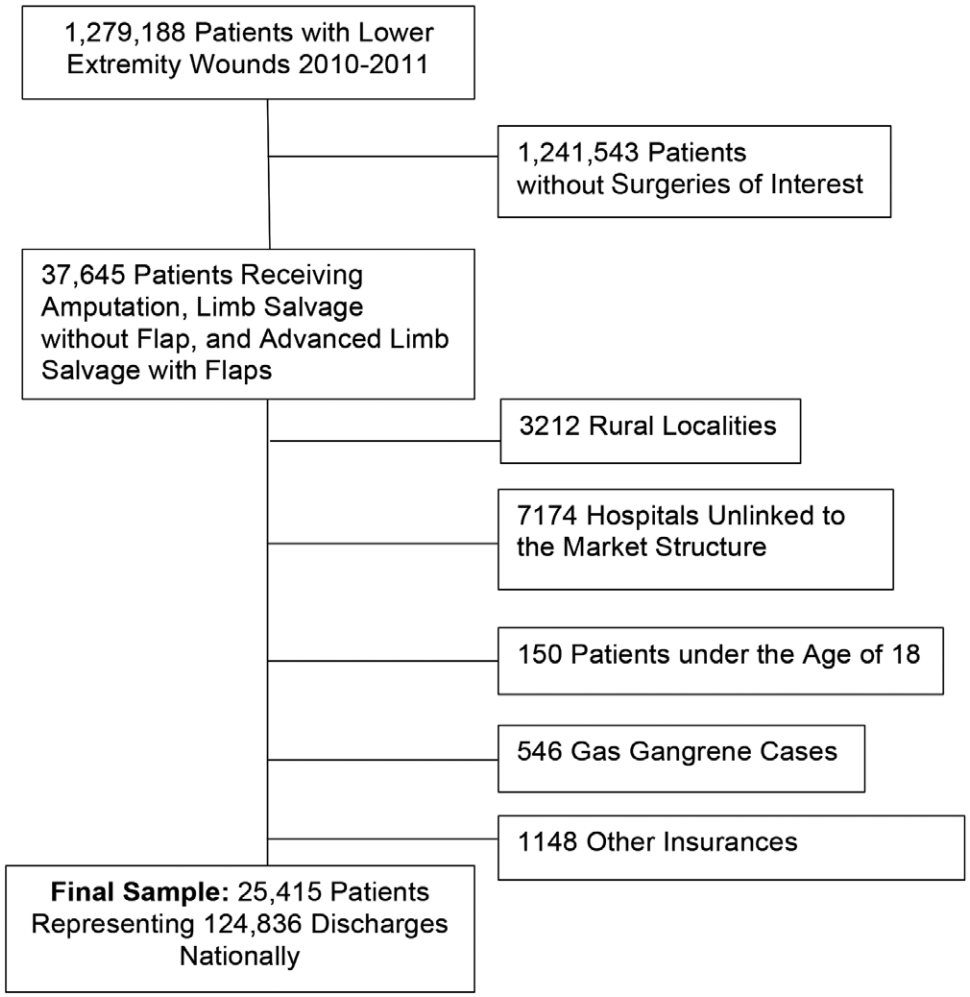

Fig. 1. Cohort selection.

by hospitals in moderately concentrated markets. Less than 1/5 of cases were done in hospitals in highly concentrated markets (18.9%) (Table 1). The majority of patients were white (53.9%) followed by African American (21.1%) or Hispanic (11.7%). The majority of cases were performed in urban teaching hospitals (56.4%). Compared with the national sample of discharges, this cohort was overrepresented by patients who were African American, covered by Medicare, and low socioeconomic status.[34]

There is a clear gradient with amputations becoming more likely and both types of limb salvage becoming less likely as hospital markets become more concentrated (Table 2). Among all surgical treatments performed by hospitals, hospitals in highly competitive environments had performed more flaps on their patients (7.85%) compared with hospitals in uncompetitive environments (3.99%) ($P < 0.0001$). Hospitals in noncompetitive environments performed more amputations (81.3%) than hospitals in competitive environments (67.8%) ($P < 0.0001$). As previously demonstrated, patients who did not receive flaps were more likely to be African American, of lower socioeconomic status, without private insurance, and without access to urban teaching hospitals ($P < 0.0001$).[14] Patients receiving lower extremity flaps tended to receive their care at urban teaching hospitals ($P = 0.0003$) and be from populaces with greater than >1,000,000 people ($P < 0.0001$).

Patients receiving amputations, compared with flap patients, were less likely to have a low Elixhauser comorbidity score, less likely to be diabetic, less likely to have ESRD, have a previous history of amputation, have peripheral vascular disease, and have a history of amputation ($P < 0.0001$) (Table 3). Patients receiving flaps had lower Elixhauser comorbidity scores and were less likely to have diabetes, ESRD, a history of previous amputation, peripheral vascular disease, or previous history of amputation ($P < 0.0001$).

The majority of lower extremity flaps for chronic wounds are performed in highly competitive environments (HHI < 1500) (70.4%) compared with moderately competitive (HHI = 1500–2500) (18.2%) and noncompetitive (HHI > 2500) (11.4%) (**see table, Supplemental Digital Content 1**, which displays patient and hospital factors by HHI, http://links.lww.com/PRSGO/B574).

There was no significant difference in the race that hospitals serve ($P = 0.154$). However, there is a tendency of treating patients with higher socioeconomic status by median income by zip code among hospitals in highly competitive environments (HHI < 1500) ($P = 0.0001$). Hospitals in highly competitive environments (HHI < 1500) tended to be in areas with populations >1,000,000 ($P < 0.0001$). Urban teaching hospitals treating lower extremity wounds also tended to be in these competitive environments (HHI < 1500) ($P < 0.0001$). There was no difference in patients' Elixhauser score between hospitals of varying levels of competition ($P = 0.366$) (**see table, Supplemental Digital Content 2**, which displays comorbidity profile by HHI, http://links.lww.com/PRSGO/B575).

However, hospitals in competitive environments did tend to treat less patients with diabetes, ESRD, and severe peripheral vascular disease ($P < 0.0001$). Competitive hospitals (HHI < 1500) also tended to perform more vascular procedures on their patients ($P = 0.209$).

According to the marginal effects from the multinomial probit model with patients- and hospital-level factors, receiving care at a hospital with high levels of competition (HHI < 1500) was the strongest protective factor in receipt of lower extremity flap for chronic wounds (Table 4). Patients receiving care at a hospital within a competitive environment were 2.48 PP more likely to receive lower extremity flaps than patients receiving care at a noncompetitive hospital with high patient concentration

Table 1. Sample Characteristics

Characteristic	Percentage*†
Year	
2010	49.05 (44.50, 53.61)
2011	50.95 (46.39, 55.50)
HHI‡	
<1500 (highly competitive)	59.17 (54.01, 64.13)
1500–2500 (moderate)	21.94 (17.80, 26.72)
>2500 (noncompetitive)	18.89 (15.51, 22.82)
Race	
White	53.94 (51.04, 56.80)
African American	21.09 (19.13, 23.18)
Hispanic	11.65 (9.86, 13.73)
Asian or other	13.32 (10.70, 16.47)
Age	
18–35	3.66 (3.28, 4.08)
36–50	13.88 (13.16, 14.64)
51–65	35.62 (34.85, 36.40)
>65	46.84 (45.50, 48.19)
Gender	
Male	62.87 (62.15, 63.58)
Female	37.13 (36.42, 37.85)
Median household income	
$1–$38,999	33.58 (31.51, 35.73)
$39,000–$47,999	25.76 (24.38, 27.18)
$48,000–62,999	24.04 (22.71, 25.43)
$63,000 or more	16.61 (14.87, 18.51)
Primary expected payer	
Medicare	63.43 (61.85, 64.99)
Medicaid	12.48 (11.46, 13.57)
Self-pay	4.51 (3.77, 5.38)
Private including HMO	19.59 (18.64, 20.57)
Location of patient's residency	
Counties with <50,000 population	12.97 (11.43, 14.69)
Counties in metro areas of 50,000–249,999 population	10.54 (8.67, 12.76)
Counties in metro areas of 250,000–999,999 population	19.19 (15.96, 22.89)
Fringe counties of metro areas of ≥1 million population	24.86 (21.82, 28.16)
Central counties of metro areas of ≥1 million population	32.44 (28.81, 36.31)
Location and teaching hospital status	
Urban teaching	56.35 (53.46, 59.21)
Urban nonteaching	43.65 (40.79, 46.54)
Bed size of the hospital§	
Small	66.61 (63.95, 69.16)
Medium	22.84 (20.66, 25.18)
Large	10.55 (9.06, 12.26)
Region of the hospital	
Northeast	7.22 (6.11, 8.50)
Midwest	24.88 (22.48, 27.44)
South	45.30 (42.42, 48.22)
West	22.60 (20.28, 25.11)

HMO, health maintenance organization.
*Numbers in parentheses are 95% confidence intervals.
†Based on a sample of 25,415 admissions representing 124,836 total admissions nationally (95% confidence interval: 117,598, 132,074).
‡HHI based on variable radius 90%.
§Actual number of beds per category varies depending on the region, as stratified by the NIS.
Source: National Inpatient Sample.

Table 2. HHI, Patient-level Factors, and Systems-level Factors by Surgical Modality

Characteristic	Amputation‡§	Limb Salvage without Flap Reconstruction‡§	Limb Salvage with Flap Reconstruction‡§
Average HHI	1822.78 (1651.87, 1993.69)	1348.64 (1209.20, 1488.08)	1310.75 (1138.56, 1482.94)
HHI*			
<1500 (highly competitive)	67.84 (65.34, 70.25)	24.3 (22.13, 26.62)	7.85 (6.96, 8.85)
1500–2500 (moderate)	75.24 (71.71, 78.45)	19.29 (16.57, 22.32)	5.48 (4.56, 6.58)
>2500 (noncompetitive)	81.26 (77.63, 84.41)	14.76 (12.00, 18.02)	3.99 (3.03, 5.22)
Year			
2010	71.33 (68.85, 73.68)	22.33 (20.24, 24.58)	6.34 (5.64, 7.11)
2011	72.64 (70.21, 74.95)	20.50 (18.54, 22.61)	6.86 (5.99, 7.84)
Race			
White	68.56 (66.34, 70.70)	23.53 (21.68, 25.49)	7.90 (7.06, 8.84)
African American	79.74 (77.41, 81.89)	16.24 (14.34, 18.33)	4.02 (3.19, 5.06)
Hispanic	74.39 (70.73, 77.74)	20.26 (17.29, 23.58)	5.35 (4.40, 6.50)
Asian or other	71.56 (67.87, 74.99)	21.93 (19.07, 25.09)	6.51 (5.55, 7.62)
Age			
18–35	40.34 (35.94, 44.90)	47.12 (42.30, 51.99)	12.54 (10.18, 15.35)
36–50	64.83 (62.17, 67.40)	28.36 (25.94, 30.92)	6.80 (5.89, 7.85)
51–65	72.03 (70.04, 73.94)	21.03 (19.41, 22.75)	6.94 (6.17, 7.79)
>65	76.57 (74.78, 78.27)	17.61 (16.14, 19.17)	5.82 (5.14, 6.58)
Gender			
Male	74.06 (72.22, 75.81)	19.79 (18.25, 21.43)	6.15 (5.52, 6.85)
Female	68.50 (66.38, 70.55)	24.14 (22.32, 26.07)	7.36 (6.58, 8.21)
Median household income			
$1–$38,999	74.99 (72.72, 77.14)	19.61 (17.68, 21.70)	5.40 (4.74, 6.15)
$39,000–$47,999	73.65 (71.44, 75.75)	19.76 (17.98, 21.66)	6.59 (5.66, 7.66)
$48,000–62,999	70.25 (67.96, 72.44)	22.57 (20.62, 24.65)	7.18 (6.26, 8.22)
$63,000 or more	65.94 (62.92, 68.83)	25.84 (23.52, 28.30)	8.22 (7.16, 9.42)
Primary expected payer			
Medicare	75.90 (74.19, 77.53)	17.90 (16.48, 19.41)	6.20 (5.54, 6.94)
Medicaid	69.32 (66.08, 72.37)	24.34 (21.53, 27.39)	6.35 (5.43, 7.40)
Self-pay	62.48 (59.77, 65.11)	29.06 (26.71, 31.53)	8.46 (7.46, 9.59)
Private including HMO	66.25 (61.71, 70.51)	28.75 (24.52, 33.39)	5.00 (3.62, 6.88)
Location of patient's residency			
Counties with <50,000 population	74.84 (71.59, 77.83)	18.94 (16.44, 21.71)	6.22 (5.05, 7.65)
Counties in metro areas of 50,000–249,999 population	77.71 (74.10, 80.95)	17.40 (14.67, 20.52)	4.89 (3.67, 6.48)
Counties in metro areas of 250,000–999,999 population	77.90 (75.13, 80.43)	16.78 (14.75, 19.02)	5.33 (4.42, 6.41)
Fringe counties of metro areas of ≥1 million population	70.29 (67.40, 73.03)	22.28 (19.90, 24.86)	7.43 (6.27, 8.78)
Central counties of metro areas of ≥1 million population	67.10 (64.00, 70.06)	25.38 (22.68, 28.29)	7.52 (6.58, 8.59)
Location and teaching hospital status			
Urban teaching	69.16 (66.48, 71.71)	23.73 (21.47, 26.13)	7.12 (6.17, 8.20)
Urban nonteaching	75.64 (73.20, 77.93)	18.30 (16.32, 20.45)	6.06 (5.34, 6.86)
Bed size of the hospital†			
Small	71.33 (68.96, 73.59)	22.17 (20.21, 24.27)	6.50 (5.73, 7.36)
Medium	73.64 (69.72, 77.22)	19.76 (16.58, 23.37)	6.60 (5.40, 8.05)
Large	72.56 (67.92, 76.76)	19.68 (16.19, 23.72)	7.76 (5.76, 10.37)
Region of the hospital			
Northeast	67.61 (60.14, 74.28)	25.01 (20.05, 30.72)	7.38 (4.55, 11.74)
Midwest	73.59 (70.36, 76.58)	19.62 (17.19, 22.29)	6.80 (5.76, 8.00)
South	73.89 (71.09, 76.52)	19.98 (17.61, 22.59)	6.12 (5.16, 7.25)
West	67.85 (63.71, 71.74)	25.05 (21.62, 28.82)	7.10 (6.08, 8.28)

Values expressed in percentages by row.
HMO, health maintenance organization.
*HHI based on variable radius 90%.
†Actual number of beds per category varies depending on the region, as stratified by the NIS.
‡All 2-way associations are statistically significant at $P < 0.001$ except for year, which shows no association with the outcome ($P = 0.36$). Numbers in parentheses are 95% confidence intervals.

(HHI > 2500) ($P = 0.008$). The probability of amputations was lower in patients treated in competitive hospitals 3.40 PP lower than in noncompetitive hospitals, but not significant ($P = 0.085$). Patients receiving care from hospitals in moderately competitive markets were less likely to receive amputation and more likely to receive limb salvage without flaps. After accounting for hospital competitions, urban teaching hospitals ($P = 0.335$) were no longer protective of receiving lower extremity flaps. However, controlling for hospital competition did not remove the effects of race. African American patients were 2.21 PP less likely to receive flaps than white patients ($P < 0.0001$). Patients with diabetes (1.19 PP, $P = 0.002$), patients with a history of amputation, patients with peripheral vascular disease (2.285 PP, $P < 0.001$), patients with a history of infection, and patients with a history of vascular intervention were all less likely to receive lower extremity flaps.

DISCUSSION

This study adds to the large literature on hospital competition and its effect on patient outcomes and social welfare. Kessler and McClellan[35] found that treatment in hospitals with greater levels of competition benefits cardiac patients by reducing adverse outcomes and costs, thereby improving social welfare. Similarly, legislation

Table 3. Comorbidity Profile by Surgical Modality

Characteristic	Amputation*†	Limb Salvage without Flap Reconstruction*†	Limb Salvage with Flap Reconstruction*†
Elixhauser comorbidity score			
<0	63.25 (60.71, 65.71)	28.89 (26.73, 31.15)	7.86 (6.93, 8.91)
1–10	72.79 (70.83, 74.67)	20.38 (18.74, 22.12)	6.83 (6.07, 7.68)
11–20	78.67 (76.88, 80.35)	15.79 (14.35, 17.34)	5.55 (4.79, 6.42)
>20	81.17 (79.09, 83.09)	13.83 (12.13, 15.72)	5.00 (4.23, 5.91)
Elective			
Yes	65.66 (63.19, 68.04)	25.74 (23.81, 27.76)	8.61 (7.60, 9.74)
No	75.84 (74.00, 77.59)	18.72 (17.13, 20.43)	5.44 (4.83, 6.12)
Diabetic			
Yes	78.59 (76.92, 80.17)	16.11 (14.75, 17.57)	5.30 (4.69, 5.99)
No	59.69 (57.24, 62.10)	31.27 (29.06, 33.57)	9.03 (8.16, 9.98)
ESRD			
Yes	68.77 (66.82, 70.65)	23.89 (22.24, 25.63)	7.34 (6.63, 8.12)
No	87.67 (86.16, 89.04)	9.31 (8.15, 10.62)	3.02 (2.47, 3.68)
History of amputation			
No history of amputation	69.79 (67.85, 71.66)	23.06 (21.42, 24.79)	7.15 (6.46, 7.90)
History of toe amputation	82.01 (79.29, 84.45)	14.72 (12.57, 17.17)	3.27 (2.39, 4.45)
History of foot or ankle amputation	78.70 (73.87, 82.84)	17.15 (13.21, 21.97)	4.15 (2.56, 6.66)
History of BKA	86.69 (84.32, 88.74)	9.98 (8.05, 12.32)	3.33 (2.41, 4.58)
History of AKA	89.91 (87.09, 92.16)	6.29 (4.52, 8.69)	3.80 (2.59, 5.55)
History of hip disarticulation	100	0	0
Smoker			
Yes	71.92 (69.33, 74.37)	22.07 (19.86, 24.45)	6.01 (5.19, 6.97)
No	72.01 (70.19, 73.77)	21.26 (19.74, 22.87)	6.72 (6.06, 7.45)
Peripheral vascular disease			
No history	54.46 (52.13, 56.76)	35.04 (32.95, 37.19)	10.50 (9.46, 11.65)
Any history of peripheral vascular disease	72.96 (70.72, 75.10)	19.88 (17.99, 21.91)	7.16 (6.34, 8.08)
Critical limb ischemia	94.02 (93.12, 94.81)	4.89 (4.20, 5.69)	1.09 (0.83, 1.43)
Infection			
No history	66.94 (64.75, 69.07)	24.19 (22.39, 26.09)	8.87 (7.99, 9.83)
Mild infection (cellulitis)	65.25 (62.86, 67.56)	28.01 (25.84, 30.28)	6.75 (5.93, 7.66)
Gangrene	90.96 (89.78, 92.02)	6.54 (5.67, 7.52)	2.50 (2.00, 3.13)
Vascular intervention in this hospital stay			
No history	70.14 (68.18, 72.02)	22.79 (21.13, 24.54)	7.07 (6.41, 7.81)
Vascular intervention	84.37 (82.42, 86.14)	12.16 (10.66, 13.85)	3.47 (2.70, 4.44)

Values expressed in percentages by row.
HMO, health maintenance organization.
*Numbers in parentheses are 95% confidence intervals.
†All 2-way associations are statistically significant at $P < 0.001$ except for year, which shows no association with the outcome ($P = 0.36$).
Source: National Inpatient Sample.

for the National Health Service in the United Kingdom to increase competition based on quality, and the ability for patients to select higher quality care decreased 30-day mortality for patients diagnosed with acute myocardial infarctionl.[36] Other research by DeLia et al[37] has linked increased hospital competition with reductions in long-standing racial disparities in use of coronary angiography.

Operating in a competitive market often leads to hospitals investing in more high-technology services and equipment, particularly surgical fields.[19–22] Wright et al[19] found the effect of market competition on access to post-mastectomy breast reconstruction to be independent of other clinical and demographic factors. Although only one-third of women in noncompetitive environments received postmastectomy breast reconstruction, over 50% of women were in receipt in competitive environments. Furthermore, competitive environment spur hospitals to adopt the technological advancements, such as endovascular aneurysm repair, laparoscopic colectomy, and robotic-assisted surgery.[20–22] Patients with an abdominal aortic aneurysm repair were 13% more likely to have the procedure performed endovascularly when hospitals were in a competitive environment.[20] Regional competition may spur hospitals to purchase costly devices, such as those required for robotic-assisted surgery.[21]

The motivation for our analysis is that issues regarding the effects of hospital competition on patient access and outcomes have not been well considered in the development of health systems and policy approaches for improving access to reconstructive procedures for chronic lower extremity wounds. Flap reconstruction is a technologically and surgically advanced procedure that requires infrastructure and a multidisciplinary approach.[6] Several capital costs are required, including an intraoperative microscope and postoperative monitoring devices. Furthermore, a well-coordinated team of plastic surgeons, vascular surgeons, orthopedic surgeons, and ancillary medical and nursing staff are also required. We hypothesized that without the threat of losing patients to other competitors, hospitals in more concentrated markets would be less likely to make these expensive and complex infrastructure investments. Additionally, among hospitals that have these capabilities in place, those in more competitive markets face greater pressure to expand these capabilities when service lines become saturated due to the risk of patients moving to other facilities with more rapidly available service. Hospitals in more concentrated markets have greater flexibility to manage saturated service lines (eg, through delays or stricter use criteria) without fear of losing patients. The analysis in this article is consistent with this hypothesis.

Table 4. Marginal Effects from the Multivariable Logistic Regression Model

Characteristic	Amputation	Limb Salvage without Flap Reconstruction RRR	Limb Salvage with Flap Reconstruction
HHI*			
<1500 (highly competitive)	−3.40	0.92	2.48‡
1500–2500 (moderate)	−2.67	1.77	0.90
>2500 (noncompetitive)	Reference		
Year			
2010	Reference		
2011	0.62	−1.12	0.50
Race			
White	Reference		
African American	2.82‡	−0.61	−2.21‡
Hispanic	−1.62	1.76	−0.14
Asian or other	0.79	0.22	−1.01
Age			
18–35	Reference		
36–50	7.25‡	−3.86†	−3.39‡
51–65	6.20‡	−4.27‡	−1.93
>65	7.48‡	−4.40‡	−3.08†
Gender			
Male	3.96‡	−3.30‡	−0.67‡
Female	Reference		
Median household income			
$1–$38,999	1.83	−1.02	−0.81
$39,000–$47,999	1.69	−1.69	0.00
$48,000–62,999	1.56	−1.25	−0.31
$63,000 or more	Reference		
Primary expected payer			
Medicare	−1.51	−0.54	2.05†
Medicaid	−0.51	−0.48	0.99
Self-pay	Reference		
Private including HMO	−2.46	−0.78	1.68
Location of patient's residency			
Counties with <50,000 population	Reference		
Counties in metro areas of 50,000–249,999 population	0.35	0.34	−0.66
Counties in metro areas of 250,000–999,999 population	−0.02	0.25	−0.23
Fringe counties of metro areas of ≥1 million population	−4.97‡	4.28‡	0.70
Central counties of metro areas of ≥ 1 million population	−7.42‡	6.47‡	0.94
Location and teaching hospital status			
Urban teaching	−0.67	1.25	−0.59
Urban nonteaching	Reference		
Bed size of the hospital§			
Small	Reference		
Medium	0.84	−0.75	−0.08
Large	−1.17	−0.19	1.36
Region of the hospital			
Northeast	Reference		
Midwest	7.68†	−5.88	−1.80
South	4.40	−2.71	−1.70
West	4.33	−1.61	−2.72
Elixhauser comorbidity score			
<0	Reference		
1–10	1.39†	−1.91‡	0.51
11–20	2.49‡	−2.82‡	0.33
>20	3.74‡	−4.18‡	0.44
Elective versus nonelective admission			
Elective	Reference		
Nonelective	3.46‡	−2.66‡	−0.81
Diabetic			
Yes	8.26‡	−7.08	−1.19†
No	Reference		
ESRD			
Yes	5.04‡	−3.54‡	−1.51
No	Reference		
History of amputation			
No history of amputation	Reference		
History of toe amputation	5.57‡	−3.35‡	−2.22‡
History of foot or ankle amputation	2.75	−1.18	−1.58
History of BKA	8.50‡	−6.12‡	−2.38‡
History of AKA	11.0‡	−10.1‡	−0.91
History of hip disarticulation	27.5‡	−20.7‡	−6.83‡
Smoker			
Yes	2.28‡	−1.59†	−0.69
No	Reference		
Peripheral vascular disease			
No history	Reference		
Any history of peripheral vascular disease	9.69‡	−6.84‡	−2.86‡
Critical limb ischemia	38.7‡	−28.3‡	10.5

(*Continued*)

Table 4. (*Continued*)

Characteristic	Amputation	Limb Salvage without Flap Reconstruction RRR	Limb Salvage with Flap Reconstruction
Infection			
No history	Reference		
Mild infection (cellulitis)	8.27‡	−3.13‡	−5.14‡
Gangrene	32.0‡	−22.8†	−9.24‡
Any vascular procedure			
Yes	3.49‡	−1.66	−1.83‡
No	Reference		

Values expressed in percentage (%) points.
*HHI based on variable radius 90%.
†Statistically significant at $P < 0.05$.
‡Statistically significant at $P < 0.01$.
§Actual number of beds per category varies depending on the region, as stratified by the NIS.
Source: National Inpatient Sample.

Previously, Fan et al[14] found access to urban teaching hospitals to be the strongest system-level predictor of receipt of limb salvage with flaps. In this analysis, we found that the urban teaching hospital effect disappears after accounting for the competitiveness of the local hospital market. This indicates that regional competition is the explanation of the protective effects previously documented for urban teaching hospitals.[14] The results of this study indicate that the protective effect of urban teaching hospitals can be explained by the more competitive markets in which these hospitals operate. We note that our measure of hospital competition is based on competition in all service lines combined. Although hospitals may invest in specific treatment capabilities to enhance their overall patient care reputation, an HHI measure based on advanced wound care for diabetes or peripheral vascular disease patients in particular might produce different, possibly stronger, results. In contrast to the work cited by DeLia et al, even after accounting for hospital competition along with other factors, limb salvage disparities between African American and white patients persisted.[37] Kronebusch et al[38] identified 11 key surgical procedures in 4 states and found that in competitive environments with multiple hospitals providing specialized services, minorities are more likely to seek low-volume centers. They argue minorities often have limited connections to physicians, lower levels of medical knowledge in their communities, and lower trust in the health system. In the setting of multiple choices with potentially varying quality, patients with historically limited access and economic power may rely on familiar low-volume centers, such as those not performing diabetic limb salvage. This may explain why adjusting for market competition did not eliminate disparities in flap reconstruction for chronic wounds in this study.

This study is subject to limitations. First, as described earlier, our analysis did not include a service line-specific measure of hospital competition. Second, the NIS tracks discharges, not patients themselves, and may therefore be subject to repeated admissions. NIS is also blinded to physician-level factors, such as referral patterns, surgical decision-making, and awareness of availability, which contribute to the surgical care received. Furthermore, the HHI provided by the HMS file is market competition for all procedures and services. The effects of competition within certain service lines cannot be analyzed with this measure.

Future studies should focus in more granular detail on individual markets for severe lower extremity wound care. These would include factors that lead to limb salvage adoption with or without flaps, at what scale, and across different market structures. To that end, detailed examination of markets may shed light on the effects of market concentration on adoption of services and help reveal a pathway to disparity reduction. Furthermore, a broader examination of hospital competition and limb salvage services should include referral patterns and other factors affecting patients before coming to the hospital for advanced wound care.

CONCLUSIONS

This study finds that patients with severe lower extremity wounds are more likely to receive amputation and less likely to receive limb salvage if they are treated in a hospital in a highly concentrated market. The level of competition versus concentration in the relevant hospital market is the strongest systems-level predictor of receipt of lower extremity flaps in patients with chronic wounds. Still, overall usage of limb salvage remains low overall and access disparities persist regardless of HMS. Further studies are needed to better understand how the dynamics of competition affect ground-level access and treatment decisions and how this knowledge can be used to develop appropriate health systems and policy interventions.

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