Supplemental Digital Appendix 1
Variable Construction Details

This appendix document provides additional details on the construction of key variables from our analysis that are not in AHRQ's publicly available Compendium of U.S. Health Systems and Hospital Linkage file.[1] We also describe the process by which we used web searches to link academic medical centers (AMCs) to medical school affiliates.

1. Academic Medical Center

Our definition of an AMC is a hospital that meets three criteria: (1) medical school affiliation, (2) significant teaching of medical residents, and (3) general acute care hospital (GACH) status. Medical school affiliation was determined by using two main data sources: the 2016 Provider of Services (POS) file[2] and the 2015 American Hospital Association's (AHA) Annual Survey.[3] We recorded hospitals as having a medical school affiliation if either the POS or AHA data indicated an affiliation, and if we the Association of American Medical Colleges (AAMC) documentation or web searches reported an affiliation with an accredited medical school in the United States (see section on "Medical School Affiliation Determination" below). If no affiliation was recorded for a hospital in either data set, we assumed the hospital had no medical school affiliation

In the POS file, we recorded a hospital as having a medical school affiliation if the variable *mdcl_schl_afltn_cd* documented the hospital as having an affiliation type of "grad," "major," or "limited," and it was recorded as not having an affiliation if the affiliation type was "no affiliation." In the AHA data, we record a medical school affiliation if the *MAPP5* variable was recorded as "yes."

We identified hospitals as major or very major teaching hospitals if they had a resident-to-bed ratio of at least 0.25. The number of residents for each hospital reflects the number of FTE residents in the Healthcare Cost Report Information System (HCRIS)[4], unless that information was not available, in which case it reflects the number of residents reported in POS, Graham Center[5], or AHA, in that order. If all sources were missing, the hospital was assumed not to be a major or very major teaching hospital.

---

[1] Agency for Healthcare Research and Quality (AHRQ). Compendium of U.S. health systems, 2016. http://www.ahrq.gov/chsp/compendium/index.html. Updated 2017. Accessed November 12, 2018.

[2] Provider of Services File: https://www.cms.gov/Research-Statistics-Data-and-Systems/Downloadable-Public-Use-Files/Provider-of-Services/

[3] American Hospital Association Annual Survey: http://www.ahadata.com/aha-annual-survey-database-asdb/

[4] Healthcare Cost Report Information System: https://www.cms.gov/Research-Statistics-Data-and-Systems/Downloadable-Public-Use-Files/Cost-Reports/

[5] The Graham Center: https://www.graham-center.org/rgc/maps-data-tools/data-tables/gme.html

We identified hospitals as general acute care hospitals (GACH) using multiple data sources and the approach used to develop the Compendium of U.S Health Systems.[6] We considered a hospital to be a GACH if it was identified as such in the AHA data, unless that information was not available, in which case it reflects data from the Healthcare Organization Services (HCOS)[7], or SK&A data[8], in that order. If none of the data sources recorded GACH status, the hospital was assumed not to be GACH. This differs from what is included in the Hospital Linkage file where a hospital was considered a GACH if any of three data sources considered a hospital to be a GACH.

2. Graduate Medical Education Spending
Data from the Graham Center for 2016, including data on GME spending or residency full time equivalents, was annualized using the most recent period available for year 2016. When more or less than 12 months of data was provided, non-bed variables (spending and resident full time equivalents) were prorated to a 12 month period, e.g. if 6 months of data were reported, the 12 month equivalent would multiply these values by a factor of two.

3. Service Provision and Affiliated Facilities
A hospital in the POS data was determined to provide a given service if it was provided by hospital staff or under arrangement: "1=provided by staff," "2=provided under arrangement," or "3=provided by staff and under arrangement." A hospital was determined not to provide a service if the service variable had the value "0=not provided."

4. Medical School Relationship
The primary data that was used to determine the link between AMCs and medical schools came from the AAMC's Council of Teaching Hospitals and Hospital Systems (COTH) Annual and Quarterly Surveys of Hospital Operations and Financial Performance (OpFin). The data included the annual survey for fiscal year 2013 through the quarterly survey for the second quarter (April through June) of 2017. Participation in the OpFin surveys is limited to AAMC COTH-member, short-term, general, and non-Federal teaching hospitals and excluded children's, specialty, and Veterans Affairs hospitals. Respondents reported the primary medical school affiliate as well as other medical school affiliates, and all affiliation information was included. AAMC provided the data for this research project as an AAMC Special Report—"Updated Hospital-to-Medical School Affiliations, as of January 26, 2018."

For hospitals that met the three criteria we used to define an AMC, but were not members of the Council of Teaching Hospitals, we supplemented AAMC data with web searches to determine medical school affiliations. We searched the hospitals website, including pages about medical education, to determine if the hospital identified as a teaching affiliate of one or more medical schools. We also searched the medical education and related pages to determine if the hospital

---

[6] https://www.ahrq.gov/sites/default/files/wysiwyg/chsp/compendium/chsp_linkage_file_tech_doc.pdf

[7] Healthcare Organization Services: http://us.imshealth.com/legal/ServicePlanDetails-HCOS.pdf

[8] SK&A: http://www.skainfo.com/

offered approved clinical rotations for medical students from one or more medical schools. We recorded a medical school affiliation (up to five for each hospital) for medical schools that met one or both of the above criteria (primary teaching affiliate and/or approved clinical rotations) and noted the type of school, allopathic or osteopathic, for each affiliation. We found we could not reliable distinguish primary medical school affiliations from secondary medical school affiliations through these web searches.

Supplemental Digital Appendix 2
Technology and Specialized Services Provided at Academic Medical Centers (AMCs) vs. at Other General Acute Care Hospitals (Non-AMCs), 2016

Variable	AMCs	Non-AMCs	P value
N	381	4660	
Service provision			
Cardiac catheterization lab	90.3%	39.5%	<0.001
Dental services	64.3%	31.1%	<0.001
Burn care unit	26.8%	2.5%	<0.001
Obstetrics services	76.9%	65.8%	<0.001
Adult inpatient psychiatric services	70.9%	28.9%	<0.001
Neonatal intensive care unit	56.7%	16.1%	<0.001
Alcohol and/or drug services	43.3%	18.4%	<0.001
Designated trauma center	58.0%	29.3%	<0.001
Coronary care unit	84.3%	46.8%	<0.001
Emergency department	96.9%	97.1%	<0.001
Diagnostic radiology services	99.2%	99.4%	0.001
Emergency psychiatric services	60.6%	34.9%	<0.001
Intensive care unit	95.5%	71.5%	<0.001
Medicare-certified transplant center	33.1%	2.5%	<0.001
Magnetic resonance imaging	76.4%	70.3%	<0.001
Neurosurgical services	69.0%	24.9%	<0.001
Nuclear medicine	98.4%	80.5%	<0.001
Cardiac thoracic surgery	78.7%	24.2%	<0.001
Non-Medicare organ transplant services	32.5%	14.3%	<0.001
Positron emissions tomography	52.0%	26.6%	<0.001
Therapeutic radiology services	85.6%	48.0%	<0.001

Data come from AHRQ's 2016 Compendium of U.S. Health Systems. Information on service provision comes from the Provider of Services file. P values reflect two-sided tests of the null hypothesis of equal means (or medians, where indicated) between the two populations.

Abbreviations: AHRQ = Agency for Healthcare Research and Quality; AMC = academic medical center.

Supplemental Digital Appendix 3
Technology and Specialized Services Provided at Academic-Affiliated Health Systems (AHSs) vs. at Non-AHSs, 2016

Variable	AHSs	Non-AHSs	P value
N	230	396	
Service provision (at any hospital in system)			
Adult inpatient psychiatric services	89.6%	74.0%	<0.001
Alcohol and/or drug services	72.2%	52.8%	<0.001
Burn care unit	47.4%	7.8%	<0.001
Cardiac catheterization lab	83.9%	74.7%	0.007
Cardiac thoracic surgery	89.6%	67.9%	<0.001
Coronary care unit	92.2%	84.8%	0.007
Dental services	87.8%	58.6%	<0.001
Designated trauma center	81.3%	52.0%	<0.001
Diagnostic radiology services	100.0%	99.7%	0.446
Emergency department	98.7%	99.0%	0.736
Emergency psychiatric services	81.7%	71.0%	0.003
Intensive care unit	96.1%	98.0%	0.161
Medicare-certified transplant center	51.3%	10.9%	<0.001
Magnetic resonance imaging	88.7%	86.1%	0.354
Neonatal intensive care unit	75.7%	48.5%	<0.001
Neurosurgical services	84.8%	66.7%	<0.001
Non-Medicare organ transplant services	60.4%	33.1%	<0.001
Nuclear medicine	99.1%	99.0%	0.862
Obstetrics services	87.8%	94.4%	0.003
Positron emissions tomography	73.5%	67.7%	0.128
Therapeutic radiology services	95.2%	90.9%	0.049

Data come from AHRQ's 2016 Compendium of U.S. Health Systems. Information on service provision comes from the Provider of Services file. P values reflect two-sided tests of the null hypothesis of equal means (or medians, where indicated) between the two populations.

Abbreviations: AHRQ = Agency for Healthcare Research and Quality; AHS = academic-affiliated health system.

Supplemental Digital Appendix 4
Distribution of Academic Medical Centers (AMCs) by the Type of Medical School Relationship of the Academic-Affiliated Health System, 2016

# of AMCs	exclusive	multiple medical schools	nonexclusive
1	31	24	121
2	5	9	11
3	1	10	4
4	0	4	0
5	1	3	0
6	0	0	0
7	0	2	0
8	0	1	0
9	0	0	0
10	0	2	0
11	0	0	0
12	0	1	0

Data come from AHRQ's 2016 Compendium of U.S. Health Systems. For more details on definitions of system types, see the Methods section.
Abbreviations: AHRQ = Agency for Healthcare Research and Quality; AHS = academic-affiliated health system; AMC = academic medical center

Supplemental Digital Appendix 5
Technology and Specialized Services Provided at Academic-Affiliated Health Systems by the Type of Medical School Relationship, 2016

	Exclusive medical school	Multiple medical schools	Single shared medical school	P value (1 v. 2)	P value (2 v. 3)	P value (1 v. 3)
N	38	56	136			
Service provision (any hospital in system)						
Adult inpatient psychiatric services	84.2%	96.4%	88.2%	0.038	0.077	0.512
Alcohol and/or drug services	68.4%	80.4%	69.9%	0.190	0.138	0.866
Burn care unit	55.3%	55.4%	41.9%	0.993	0.090	0.145
Cardiac catheterization lab	86.8%	96.4%	77.9%	0.084	0.002	0.229
Cardiac thoracic surgery	89.5%	96.4%	86.8%	0.180	0.047	0.659
Coronary care unit	97.4%	98.2%	88.2%	0.783	0.027	0.095
Dental services	84.2%	96.4%	85.3%	0.038	0.028	0.869
Designated trauma center	89.5%	96.4%	72.8%	0.180	<0.001	0.032
Diagnostic radiology services	100.0%	100.0%	100.0%	.	.	.
Emergency department	97.4%	100.0%	98.5%	0.227	0.364	0.629
Emergency psychiatric services	78.9%	96.4%	76.5%	0.007	0.001	0.750
Intensive care unit	97.4%	98.2%	94.9%	0.783	0.292	0.516
Medicare-certified transplant center	42.1%	66.1%	47.8%	0.021	0.021	0.537
Magnetic resonance imaging	94.7%	98.2%	83.1%	0.352	0.004	0.071
Neonatal intensive care unit	78.9%	89.3%	69.1%	0.171	0.003	0.239
Neurosurgical services	86.8%	96.4%	79.4%	0.084	0.003	0.304
Non-Medicare organ transplant services	55.3%	69.6%	58.1%	0.158	0.136	0.757
Nuclear medicine	100.0%	100.0%	98.5%	.	0.364	0.455
Obstetrics services	94.7%	96.4%	82.4%	0.694	0.009	0.059
Positron emissions tomography	84.2%	87.5%	64.7%	0.654	0.001	0.022
Therapeutic radiology services	97.4%	96.4%	94.1%	0.802	0.515	0.427

Data come from AHRQ's 2016 Compendium of U.S. Health Systems. Information on service provision comes from the Provider of Services file. P values reflect two-sided tests of the null hypothesis of equal means (or medians, where indicated) between the two populations.

Abbreviations: AHRQ = Agency for Healthcare Research and Quality; AHS = academic-affiliated health system.

Supplemental Digital Appendix 6
Comparison of the Characteristics of Academic-Affiliated Health Systems (AHSs) Affiliated with a Single, Shared Medical School, by Number of Health Systems Affiliated with the Medical School, 2016

	2 systems	3–4 systems	5+ systems	P value	P value	P value
N	38	67	31			
Size						
Small (1–2 general acute care hospitals)	44.7%	52.2%	48.4%	0.465	0.726	0.766
Medium (3–6 general acute care hospitals)	39.5%	25.4%	32.3%	0.134	0.483	0.542
Large (7+ general acute care hospitals)	15.8%	22.4%	19.4%	0.421	0.737	0.703
System characteristics						
Median bed count	790.5	631.0	623.0	0.376	0.936	0.271
Median % of beds in AMCs	88.3%	100.0%	100.0%	.	.	0.152
Median count of physicians	961.5	756.0	508.0	0.196	0.343	0.038
Median count of primary care physicians	244.5	223.0	193.0	0.376	0.515	0.537
Median count of specialist physicians	740.0	527.0	295.0	0.196	0.277	0.113
Median ratio of primary care physicians to specialists	0.4	0.5	0.6	0.018	0.128	0.022
Includes safety net hospital	36.8%	41.8%	61.3%	0.623	0.074	0.044
Includes any children's hospitals	23.7%	22.4%	6.5%	0.881	0.053	0.053
Multistate system (3 or more states)	5.3%	3.0%	3.2%	0.562	0.949	0.685
More than one AMC in system	7.9%	14.9%	6.5%	0.298	0.238	0.821
Characteristics of graduate medical education						
Median total resident full-time equivalents per system	332.3	228.7	188.0	0.035	0.277	0.002
Median spending on total graduate medical education per system	$26,470,178	$23,453,963	$20,650,902	0.631	0.515	0.271
Median spending on direct graduate medical education per system	$8,560,564	$6,209,929	$6,528,907	0.376	0.828	0.271
Median % of general acute care hospitals that are AMCs	50.0%	50.0%	50.0%	0.519	0.862	0.484
Any AMCs with allopathic medical school affiliation	100.0%	95.5%	96.8%	0.189	0.774	0.271
Any AMCs with osteopathic medical school affiliation	0.0%	4.5%	3.2%	0.189	0.774	0.271
Both allopathic and osteopathic medical school affiliations in system	0.0%	0.0%	0.0%	.	.	.
Service provision (at any hospital in system)						

Mean number of services provided	12.7	12.5	12.2	0.784	0.661	0.506
At least 1 hospital providing all 21 services	13.2%	4.5%	3.2%	0.109	0.774	0.150
Adult inpatient psychiatric services	89.5%	85.1%	93.5%	0.529	0.238	0.557
Alcohol and/or drug services	68.4%	65.7%	80.6%	0.777	0.134	0.256
Burn care unit	60.5%	37.3%	29.0%	0.022	0.428	0.009
Cardiac catheterization lab	84.2%	76.1%	74.2%	0.332	0.839	0.310
Cardiac thoracic surgery	89.5%	91.0%	74.2%	0.795	0.027	0.099
Coronary care unit	86.8%	89.6%	87.1%	0.678	0.724	0.976
Dental services	84.2%	85.1%	87.1%	0.907	0.793	0.739
Designated trauma center	76.3%	76.1%	61.3%	0.982	0.133	0.182
Diagnostic radiology services	100.0%	100.0%	100.0%	.	.	.
Emergency department	100.0%	98.5%	96.8%	0.454	0.577	0.271
Emergency psychiatric services	73.7%	76.1%	80.6%	0.784	0.622	0.503
Intensive care unit	97.4%	95.5%	90.3%	0.639	0.323	0.219
Medicare-certified transplant center	63.2%	41.8%	41.9%	0.036	0.989	0.081
Magnetic resonance imaging	84.2%	80.6%	87.1%	0.648	0.435	0.739
Neonatal intensive care unit	68.4%	70.1%	67.7%	0.855	0.812	0.953
Neurosurgical services	84.2%	77.6%	77.4%	0.421	0.983	0.480
Non-Medicare organ transplant services	63.2%	62.7%	41.9%	0.962	0.055	0.081
Nuclear medicine	94.7%	100.0%	100.0%	0.059	.	0.200
Obstetrics services	76.3%	83.6%	87.1%	0.367	0.657	0.261
Positron emissions tomography	68.4%	70.1%	48.4%	0.855	0.038	0.094
Therapeutic radiology services	97.4%	97.0%	83.9%	0.918	0.019	0.049
Any affiliated Medicare participating services						
Ambulatory surgery centers	5.3%	6.0%	6.5%	0.882	0.927	0.837
End-stage renal disease units	34.2%	13.4%	38.7%	0.012	0.004	0.704
Home health agencies	23.7%	22.4%	29.0%	0.881	0.482	0.621
Hospices	15.8%	14.9%	16.1%	0.907	0.879	0.970
Skilled nursing facilities	21.1%	16.4%	22.6%	0.558	0.469	0.881
Plurality ownership (bed weighted)						
Investor	0.0%	1.5%	6.5%	0.454	0.189	0.115

Nonprofit, not religious	68.4%	68.7%	64.5%	0.980	0.688	0.737
Nonprofit, religious	2.6%	10.4%	9.7%	0.150	0.908	0.219
Public	28.9%	19.4%	19.4%	0.267	0.996	0.365

Data come from AHRQ's 2016 Compendium of U.S. Health Systems. For more details on definitions of system types, see the Methods section. We defined safety net hospitals as the top quintile of Medicare DSH patient percentage nationally. Information on service provision comes from the Provider of Services file. We defined ownership based on owning a plurality of hospital beds at general acute care hospitals within systems. P values reflect two-sided tests of the null hypothesis of equal means (or medians, where indicated) between the two populations.

Abbreviations: AHRQ = Agency for Healthcare Research and Quality; AHS = academic-affiliated health system; AMC = academic medical center; DSH = Disproportionate-Share Hospital.