**Supplementary Appendix**

**Sample Definition Details**

**List of HIE Networks:** We reviewed the list of networks that were represented in the Definitive data with multiple subject matter experts to confirm that hospitals that participated in the same network were typically able to exchange patient information with one another. Based on these discussions, we revised the list of included networks and in some cases combined networks (i.e., when the same network had two different names; Appendix Table 1). Hospitals were counted as participating in a community HIE network only if they were listed as participating in that network in Definitive data. The Definitive data includes 95 unique community HIE networks. Hospitals were counted as participating in a national or vendor network if they reported participating in on the AHA IT Supplement or in the Definitive data. The AHA IT Supplement included 5 named national networks while definitive data includes 34 named national and vendor networks. Hospitals could participate in multiple networks.

**Sample Construction:** We first selected all Short-Term Acute Care Hospital and Critical Access Hospitals that were included in both the Definitive data and in the 2018 AHA Annual Survey data. For the vast majority of hospitals, matching across sources was done using the hospital’s Medicare Provider Number and when that wasn’t available, by national provider identifier. 4,513 of 4,518 non-federal acute care hospitals in the AHA Annual Survey were matched.

From this population, only 2,862 (63% of 4,513) hospitals that responded to the 2018 AHA IT Supplement were included in the analytic sample.

Hospitals that were not listed as participating in a community HIE network in the Definitive data but were listed in the AHA IT supplement as participating in a community HIE network were excluded from the sample because we determined the absence of a named network in Definitive may have been due to missing data. (Unfortunately, the AHA IT Supplement does not include the name of the community HIE network to allow us to follow the same approach as the national and vendor networks.) This excluded 1,129 hospitals.

Finally, we excluded 12 hospitals that did not treat at least 11 of the same Medicare beneficiaries as one other hospital in 2018, as determined in DocGraph’s HOP data (i.e., they were not present in any pair relationships).

Our final sample therefore includes 1,721 Short-Term Acute Care Hospital and Critical Access Hospital that had complete and consistent HIE network participation data from the two sources (Definitive and AHA IT Supplement). See Appendix Table 2 below for details on hospitals in versus out of the sample. We then merged the hospital-level sample to data on hospital pairs that treated at least 11 of the same Medicare patients over the course of a year, using the hospitals’ NPI. We removed pairs that included hospitals in the same multi-hospital system in the AHA Annual Survey because these pairs were likely to use the same instance of an EHR and not rely on an HIE network. 90% of these pairs indicated that they were on the same EHR vendor. This resulted in dropping 1,951 pairs. The median number of pairs each hospital participated in was 13. Our final analytic dataset included 16,433 pairs and 6,492,232 shared patients.

**Appendix Table 1. Named National/Vendor and Community HIE Networks (2018)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **National and Vendor Network** | **n (total= 1,721)** | **Community Network** | **n (total= 1,721)** | **Community Network** | **N****(total= 1,721)** | **Community Network** | **n (total= 1,721)** |
| eHealth Exchange (FKA: Nationwide Health Information Exchange) | 826 | Kansas Department of Health and Environment (FKA Kansas Health Information Exchange KHIE) | 82 | Massachusetts eHealth Institute (MeHI)/Massachusetts Health Information Highway | 13 | Llano Estacado Access Partners (LEAP) | 4 |
| CommonWell Health Alliance | 701 | Ohio Health Information Partnership (OHIP)/CliniSync | 77 | Nebraska Health Information Initiative Inc (NeHII) | 13 | Memorial Healthcare System (MHS) HIE/Atlantic Coast HIE | 4 |
| The Sequoia Project - Carequality | 693 | Kansas Health Information Network (KHIN) | 45 | State Health Alliance for Records Exchange (SHARE) | 13 | New Jersey Southern Health Information Network Exchange (NJSHINE) | 4 |
| Care Everywhere | 590 | Healthix (FKA Brooklyn Health Information Exchange) | 42 | West Virginia Health Information Network (WVHIN) | 12 | Health Alliance for the Uninsured | 3 |
| Dbmotion/The Dbmotion Solution | 38 | Missouri Health Connection (AKA Missouri Health Information Exchange) | 42 | Alabama HIE/OneHealthRecord | 11 | Lakelands Rural Health Network (AKA Lakelands Cares) | 3 |
| Mckesson/Relayhealth Enterprise Hie/Clinical Exchange Hie | 35 | ConnectVirginia | 39 | Georgia Health Information Network (FKA Georgia Health Information Exchange) | 11 | North Coast Health Information Network (NCHIN) | 3 |
| Siemens Healthcare/Mobilemd | 32 | North Texas Accountable Healthcare Partnership | 34 | Integrated Care Collaboration | 11 | Pennsylvania Mountains Healthcare Alliance | 3 |
| Healthland/Centriq | 21 | Chesapeake Regional Information System for our Patients (CRISP) | 33 | Rochester RHIO | 11 | SunCoast RHIO Inc | 3 |
| Orion Health Hie | 20 | Great Lakes Health Connect (FKA Michigan Health Connect-GLHIE) | 33 | SacValley MedShare | 11 | Wichita Health Information Exchange (WHIE) | 3 |
| Orion Health/Rhapsody | 13 | Iowa e-Health | 30 | HealthBridge by the Health Collaborative | 10 | Community Choice Healthcare Network | 2 |
| Carealign | 12 | Colorado Regional Health Information Organization (CORHIO) | 28 | Upper Peninsula Health Information Exchange (UPHIE) | 10 | Delta Health Alliance - Delta BLUES Beacon Community | 2 |
| Optum Health Information Exchange | 12 | Florida HIE | 28 | Vermont Information Technology Leaders (VITL) | 10 | Greater New Orleans HIE | 2 |
| Sandlotconnect | 10 | Wisconsin Statewide Health Information Network (WISHIN) | 28 | Coalition of Health Services | 8 | Health Information Exchange of Montana (HIEM) | 2 |
| Caradigm/Microsoft Corporation/Amalga | 9 | New England Healthcare Exchange Network (NEHEN) | 26 | Healthcare Information Xchange of New York (AKA Hixny) | 8 | Healthcare Access San Antonio | 2 |
| Electronic Health Exchange (eehx) | 9 | Utah Health Information Network/Clinical Health Information Exchange (UHIN/cHIE) | 26 | Lincoln Land HIE | 8 | HealthLINC HIE | 2 |
| Cloverleaf Hosted Health Information Exchange | 6 | HealthInfoNet | 25 | Michiana Health Information Network | 8 | LCF Research/New Mexico Health Information Collaborative (NMHIC) | 2 |
| Data Express | 4 | Jersey Health Connect | 24 | Idaho Health Data Exchange (IHDE) | 7 | Trenton Health Information Exchange (AKA Trenton Health Team) | 2 |
| Collabornet | 3 | Southeast Michigan Health Information Exchange (SEMHIE) | 24 | Illinois Health Exchange Partners | 7 | Chatham HealthLink (HIE)/Chatham County Safety Net Planning Council | 1 |
| Iatric Systems Inc./Enterprise Hie | 3 | HealthShare Exchange of Southeastern Pennsylvania (HSX) | 23 | Keystone HIE | 7 | East Tennessee Health Information Network (etHIN) | 1 |
| Truven Health Analytics/Hie Advantage | 3 | South Carolina HIE (SCHIEx) | 22 | North Dakota Health Information Network (NDHIN) | 7 | Fresno Healthy Communities Access Partners | 1 |
| Healthcare Management Systems Inc. | 2 | Louisiana Health Information Exchange/Louisiana Health Care Quality Forum (LaHIE/LHCQF) | 21 | Pioneer Valley Information Exchange (PVIX) | 7 | Jackson Community Medical Record | 1 |
| Yourcarecommunity | 2 | ClinicalConnect Health Information Exchange | 20 | Bronx RHIO | 6 | Kentucky Governors Office of Electronic Health Information (AKA Kentucky HIE) | 1 |
| Certify Healthlogix Hie Platform | 1 | Indiana Health Information Exchange | 20 | NY Care Information Gateway (FKA eHealth Network of Long Island) | 6 | North Carolina Community Care Informatics Center | 1 |
| Covisint | 1 | Mission Health Connect | 20 | Quality Health Network (QHN) | 6 | OnePartner HIE (OPHIE) | 1 |
| Harris Corporation/Carefx/Fusion Fx | 1 | OCHIN Inc | 20 | Delaware Health Information Network (DHIN) | 5 | Texas Organization of Rural and Community Hospitals (TORCH) | 1 |
| Hiebus | 1 | Communities of Illinois Health Information Exchange (CIHIE) | 19 | HEALTHeLINK - Western New York Clinical Information Exchange | 5 | Virtua Health HIE | 1 |
| Iguana | 1 | Manifest MedEx | 19 | HealtHIE Nevada | 5 |  |  |
| Initiate Exchange | 1 | Health Current (FKA Arizona Health-e Connection) | 17 | Lewis and Clark Information Exchange (LACIE) | 5 |  |  |
| Iod Incorporated/Prism Connect | 1 | San Diego Health Connect (San Diego Regional Health Information Exchange) | 16 | Orange County Professional RHIO (AKA OCPRHIO) | 5 |  |  |
| Population Health Management | 1 | Carolinas HealthCare System CareConnect | 15 | Paso del Norte HIE | 5 |  |  |
| Primesuite | 1 | OneHealthPort/Washington HIE | 15 | South Dakota Health Link (South Dakota Department of Health) | 5 |  |  |
| Self-developed | 1 | HealtheConnections RHIO Central New York | 14 | Tiger Institute Health Alliance | 5 |  |  |
|  |  | Myhealth Access Network (FKA:Secure Medical Records Transfer Network (SMRTNET)) | 14 | Coastal Carolinas Health Alliance/Coastal Connect Inc | 4 |  |  |
|  |  | Greater Houston HealthConnect | 13 | Hawaii Health Information Exchange | 4 |  |  |

Note: n refers to the number of hospitals, out of the 1,721 in the sample, that participated in each HIE network.

**Appendix Table 2. Hospital Characteristics: In vs Out of Sample**

|  |  |  |  |
| --- | --- | --- | --- |
|  Non-federal, short-term acute care hospitals | In Analytic Sample (n=1,721) | Not in Sample (n=2,827) |   |
| **Size** |  |  |  |
| Small (<100 beds) | 46% | 56% |  |
| Medium (100-399 beds) | 41% | 36% | <0.001 |
| Large (400+ beds) | 13% | 8% |  |
| **System Membership** | 67% | 63% | <0.001 |
| **Teaching Status** |   |   |   |
| Not Teaching | 57% | 70% |  |
| Minor Teaching | 35% | 26% | <0.001 |
| Major Teaching | 8% | 4% |   |
| **Ownership Status** |   |   |   |
| Not For Profit | 21% | 21% |  |
| For Profit | 68% | 55% | <0.001 |
| Government | 11% | 23% |  |
| **Critical Access Hospital** | 26% | 32% | <0.001 |
| **Core-Based Statistical Area** |   |   |   |
| Metropolitan | 64% | 58% |  |
| Micropolitan | 16% | 17% | <0.001 |
| Rural | 19% | 26% |   |

**Appendix Table 3. Connectivity between pairs of hospitals with and without weights.**

|  |  |  |
| --- | --- | --- |
|  | **Hospital Pairs****(n=16,433)** | **Weighted %1** |
| Number of Shared PatientsMean(SD) | 395 (1200) |  |
| Neither has HIE Network:N (%) | 178 (1%) | 2% |
| Only one has HIE Network:N (%) | 2,818 (17%) | 21% |
| Both have HIE Network: DIFFERENT:N (%) | 4,499 (27%) | 14% |
| Both have HIE Network: SAME:N (%) | 8,938 (54%) | 64% |
| Both have HIE Network: SAME National/Vendor Network2:N (%) | 5,202 (32%) | 34% |
| Both have HIE Network: SAME Community Network2:N (%) | 5,251 (32%) | 47% |

Notes: 1Weights account for Volume of Shared Patients and Inverse Probability of Inclusion. 2Both hospitals in a pair could be connected by participation in the same national/vendor network and the same community network, and this occurs for 10% of all pairs. Given this overlap participation in the same national/vendor network and same community network (32%+32%=64%) is ten percentage points higher than participation in the same HIE network in the column above (54%).

**Appendix Table 4. Full Model Results: Relationship between Hospital Pair Characteristics and Likelihood that Hospitals are Connected via HIE Network(s) (2018)**

|  |  |  |
| --- | --- | --- |
| VARIABLES | Connected by participation in Same Network(s) | 95% CI |
| **Number of Shared Patients by Pair (Median) (Omitted: Very Low (30))** |
| Low (119) | 3.7\*\* | (0.0 - 7.3) |
| Medium (453) | 9.5\*\*\* | (4.4 - 14.5) |
| High (1,872) | 15.9\*\*\* | (8.0 - 23.9) |
| **Importance to Partner within Pair** |
| High Importance to Smaller Hospital | -1.1 | (-6.6 - 4.4) |
| High Importance to Larger Hospital | 2.0 | (-4.7 - 8.8) |
|  |  |  |
| **Number of Partners for Each Hospital in Pair (Omitted: Low & Low)** |
| Low & High | -9.6\*\*\* | (-16.8 - -2.4) |
| High & High | -1.5 | (-13.1 - 10.0) |
|  |
| **Distance** |
| Per 1,000 Miles | -30.5\*\* | (-54.7 - -6.3) |
| Per 1,000 Miles Squared | 7.1\*\* | (0.2 - 14.1) |
|  |
| **Hospital Ownership for Each Hospital in Pair (Omitted: Both Non-Profit)** |  |  |
| Both Government | -14.9\*\* | (-28.1 - -1.6) |
| Government & Non-Profit | -2.1 | (-9.6 - 5.4) |
| Government & For-Profit | -29.0\*\*\* | (-45.5 - -12.5) |
| Non-Profit & For-Profit | -14.8\*\* | (-26.2 - -3.4) |
| Both For-Profit | -35.1\*\*\* | (-54.4 - -15.7) |
| **Hospital System Membership for Each Hospital in Pair (Omitted: Neither in System)** |
| One in System | -7.4\*\* | (-14.6 - -0.2) |
| Both in Different Systems | 0.4 | (-8.7 - 9.5) |
|  |  |  |
| **Core-based Statistical Area of Each Hospital in Pair (Omitted: Both Metro)** |  |  |
| One Metro & One Micro | -5.8 | (-14.1 - 2.5) |
| One Metro & One Rural | -19.5\*\*\* | (-31.8 - -7.1) |
| Both Micro | -8.3 | (-33.4 - 16.7) |
| One Micro & One Rural | -9.7 | (-24.4 - 4.9) |
| Both Rural | -29.3\*\*\* | (-45.3 - -13.3) |
| **Market Competition for Each Hospital in Pair (Omitted: Both Low)** |  |  |
| Low & Medium | -5.5 | (-13.0 - 2.1) |
| Low & High | -5.6 | (-14.9 - 3.7) |
| Medium & Medium | -13.4\*\* | (-24.1 - -2.6) |
| Medium & High | -6.6 | (-17.8 - 4.6) |
| High & High | -14.9\*\* | (-27.0 - -2.9) |
| **ACO (Omitted: Neither in ACO)** |
| One in ACO | 3.2 | (-4.6 - 11.0) |
| Both in ACO | 12.2\*\* | (1.8 - 22.6) |
| **Hospital Size for Each Hospital in Pair (Omitted: Both Small)** |  |  |
| Small & Medium | -0.8 | (-10.4 - 8.8) |
| Small & Large | 10.6\* | (-1.7 - 22.9) |
| Medium & Medium | 0.2 | (-13.3 - 13.8) |
| Medium & Large | 3.7 | (-11.6 - 19.0) |
| Large & Large | 10.3 | (-6.0 - 26.6) |
|  |  |  |
| **Teaching Status of Each Hospital in Pair (Omitted: Both non-Teaching)** |  |  |
| Non-teaching and Minor | 0.2 | (-8.8 - 9.2) |
| Non-teaching and Major | -2.7 | (-15.8 - 10.3) |
| Both Minor | 1.1 | (-11.5 - 13.6) |
| Minor and Major | 6.3 | (-7.1 - 19.7) |
| Both Major | -2.3 | (-19.9 - 15.3) |
|  |  |  |
| Constant | 66.5\*\*\* | (49.7 - 83.3) |
|  |  |  |
| Observations | 6,491,388 |  |
| R-squared | 0.18 |  |
| Robust 95% Confidence Interval in parentheses |
| \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 |  |  |

Notes: Coefficients are derived from linear regression and can be interpreted as marginal increases in the percentage point probability of being connected given a one unit increase in the independent variable (or that the binary indicator is True). Estimates are weighted by the inverse probability of sample inclusion among all pairs in the population.

**Appendix Figure 1. Euler Diagram of Network Overlap among Hospital Pairs for Community HIE Networks and Individual National HIE Networks**



Notes: PCDH is too small to be represented; numbers reflect the percent of all patients shared between hospitals in our sample that were shared by hospitals connected by each combination of methods.