Title:

Linking individual-level data on diagnoses and dispensing for research on antibiotic use:

evaluation of a novel data source from English secondary care

Running title:

Evaluation of linkage in Hospital Treatment Insights (HTI)

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Key messages:

- The Hospital Treatment Insights (HTI) database links admissions, diagnoses and procedures in the widely-used Hospital Episode Statistics (HES) database with dispensing information stored in hospital pharmacy systems for a subset of 43/153 acute hospital trusts in England.

- Available from January 2010, HTI for the first time allows to analyse associations between diagnoses and hospital dispensing for individual patients in a relatively large number of NHS hospitals.

- Successful linkage of diagnoses and dispensing depends on HES and the local pharmacy systems having a minimum number of patient identifiers in common such as the NHS number, date of birth, gender and postcode. While HES contains identifiers for every patient, hospital pharmacies only retain identifiers when drugs are ordered specifically for a named patient. Where medication is administered from drugs stored on the ward without informing the pharmacy about the receiving patient, the dispensation cannot be linked to HES and is therefore not captured in HTI.

- Linkage of antibiotic dispenses was found to vary with individual antibiotic and ward settings. Capture of dispensing was good for specific antibiotics, but low linkage of highly-used treatments prevents HTI from being used for widespread antibiotic surveillance.

- Principles and findings may be generalised to other drug classes. For each drug of interest, the proportion of dispenses captured should be taken into account when designing future studies using HTI.

Prior presentations:

An abstract for this study was displayed as a poster at the International Conference on Pharmacoepidemiology & Therapeutic Risk Management 2017 in Montreal. The study was entirely funded by QuintilesIMS UK, the custodian of the HTI database.

Abstract

1

Purpose: There has been a focus on stewardship programmes to curb inappropriate antibiotic prescribing and reduce antimicrobial resistance. In-hospital, patient-level prescribing linked to indication is needed to support surveillance, evaluation of stewardship initiatives, as well as other antibiotic research. We evaluated whether a novel dataset linking hospital pharmacy records to Hospital Episode Statistics (HES) data can be used for antibiotic research.

7

Methods: Using the Hospital Treatment Insights (HTI) database, which links HES to pharmacy records from 43 out of 153 hospital trusts in England, we estimated the proportion of missed linkage and identified characteristics associated with missing data.

11

Results: Linkage of antibiotics to patients was inconsistent and dependent on drug type and clinical setting, so that linkage for some specific antibiotics was high (80-100%), but overall, only 27.6% (CI: 27.4% - 27.8%) for all antibiotics dispensed. Linkage was best for quinolones (62.6%; CI: 61.8% - 63.8%), but only 21.1% (CI: 21.1% - 21.2%) for penicillins. Linkage was lower for common antibiotics and in emergency departments, however 80% linkage was achieved for individual drugs like clindamycin, especially on wards with reduced ward stock use.

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Conclusions: For those antibiotics with high linkage, HTI might be used to study associations between indication, dispensing and outcomes. However, the majority of common antibiotics had insufficient linkage, likely due to extensive use of ward stocks. Therefore, HTI in its current form is not suitable for general antibiotic surveillance or evaluation of stewardship initiatives. For drugs in HTI other than antibiotics, linkage should be similarly evaluated before a study is conducted.

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Introduction

Owing to a continued rise in resistance[1] and a slowing in the development of new antibiotics,[2] antimicrobial resistance (AMR) is currently poised to threaten the way we think about healthcare. A recognised risk factor for the emergence of resistance is excessive use of antibiotic treatment.[3] To tackle this issue, antimicrobial stewardship (AMS) programmes are being implemented across the world to promote the effective use of antibiotics.[4–7] In hospitals, appropriate and prudent treatment is particularly important, because the combination of vulnerable patients with high rates of co-morbidity, frequent antibiotic use[2] and heavy dependence on broad-spectrum agents can create potent hotspots of AMR.[3]

To facilitate effective and efficient AMR policies, further research on the uptake and impact of current hospital interventions is urgently needed. These efforts are hampered by the unavailability of longitudinal patient-level data due to a continued lack of wide-spread electronic prescribing in English secondary care.[8] As a result, only aggregated data on hospital prescribing exists on a national level.[9] While this aggregated information allows us to monitor overall trends in antibiotic usage, it prevents detailed enquiry into the association between indication and prescribing. Any impact specifically attributable to initiatives is difficult to discern from general trends in the population.[3]

Linking information between the Hospital Episode Statistics (HES) database and the dispensing records stored in hospital pharmacy databases might offer a solution. However, success depends on these databases having a minimum number of patient identifiers in common such as the NHS number, date of birth, gender and postcode. While HES contains identifiers for every patient, hospital pharmacies only retain identifiers when drugs are ordered specifically for a named patient. Where a medication is instead stored on the ward, clinical personnel can

53 administer it without informing the pharmacy about the receiving patient. In this case, no patient

54 identifier is entered into the pharmacy system and the dispensation cannot be linked to HES.

55

56 We set out to evaluate the extent of this issue and to explore whether a linkage approach can

57 be utilised for research on antibiotic usage and surveillance in English hospitals. We described

58 the proportion of observed antibiotic dispensing after linkage using the Hospital Treatment

59 Insights (HTI) dataset, which links HES records with patient records from hospital pharmacies

60 for 43 English trusts. We compared total dispensing within all HTI hospitals against aggregated

61 pharmacy data on the hospital-level used by Public Health England.[9] We estimated the

62 proportion of dispensed antibiotics that were captured in the database and investigated factors

63 influencing the recording of data.

64

65 **Methods**

66

67 *Data sources*

68

69 Hospital Treatment Insights[1] is a database of electronic health records from English secondary

70 care. It is maintained by QuintilesIMS (https://www.quintilesims.com), a leading provider of

71 information, services and technology for the healthcare industry. HTI links hospital patient

72 records in the HES[2] database with dispensing information stored in hospital pharmacy systems

73 for a subset of 43 consenting trusts out of a total of 153 acute hospital trusts in England. In

74 these participating trusts, HES already routinely captures hospital activity information such as

75 demographics, admission and administrative data, diagnoses and procedures. Where

76 dispensing data could be linked to patients, HTI retrospectively enriches the available HES data

77 from 2010 onwards with patient-level data on brand, type, date and quantity of dispensed drugs.

78 Linkage was performed by NHS Digital as a trusted third party using a 15-step deterministic

79 linkage algorithm (Supplement Table 1). Due to the data sharing agreement with NHS Digital,

80 no information on the nature of the trusts (e.g. geography or specialty of the hospital) included

81 in HTI was made available to the researchers. Therefore, data had to be treated as if it

82 originated from a single hospital.

83

84 Between 2010 and 2015, HTI included 7.7 million admitted hospital patients (Figure 1). For 3.6

85 million (47.2%) of these patients, additional information on dispensed drugs was available. 3.9

86 million (52.8%) patients had no medication information in HTI. Although some of these patients

87 might genuinely not have been prescribed a drug, it is more likely that most of them received a

88 drug but, for reasons exemplified below, dispensing could not be linked to the patient within HTI.

89 Diagnoses and issued medications in HTI are not jointly recorded in the same IT system at the

90 point of care. Instead, they are mapped at a later point in time by NHS Digital based on

91 personal identifiers recorded in hospital pharmacy systems during dispensation. This can be

92 done if medication is explicitly requested for a named patient. If instead the drug is bulk-

93 dispensed to the hospital ward for interim storage and used on demand, hospital pharmacy

94 systems do not obtain feedback as to which patient eventually received the medication. Without

95 this information, medication from ward stock cannot be linked and has to be excluded from HTI.

96 This might happen for example in day case patients, who account for 35.1% of all inpatient

97 episodes[10]. These day case patients bring in their own medication and may only require

98 additional ward stock anaesthesia for procedures such as cataract surgery or endoscopy. They

99 may therefore account for many of the patients without any medication information. A further

100 clinical inpatient setting with possibly high ward stock usage and no additional drugs would be

101 maternity care of women without comorbid disease. Whether HTI can indeed be used for

102 antibiotic research on drug usage depends largely on the extent to which similar issues prevent

103 HTI from accurately capturing antibiotic dispensing.[11]

104

105 Aggregated reference levels of antibiotic dispensing in HTI hospitals were taken from the

106 Hospital Pharmacy Audit (HPA) database, which has been used for antibiotic surveillance by

107 Public Health England.[9] Analogous to HTI, HPA is curated by QuintilesIMS and collected from

108 hospital pharmacy systems, covering 99% of hospital beds in England.[12] However, unlike HTI it

109 does not contain patient specific information and is not, therefore, subject to data linkage. As a

110 result, HPA includes bulk dispensing to wards excluded in HTI, allowing for it to be used as a

111 measure of total hospital dispensing.

112

113 *Study design*

114

115 We conducted a retrospective cross-sectional study evaluating the proportion of antibiotic

116 treatment that could be linked to a patient in English hospitals contributing to HTI between 1st

117 April 2011 and 31st March 2015. Systemic antibiotics were defined using the classes *J01* and

118 *J03A* of the European Pharmaceutical Market Research Association's anatomical classification

119 used in both HTI and HPA.[13] This definition is roughly equivalent to the class *J01* in the World

120 Health Organisation's substance-based Anatomical Therapeutic Chemical (ATC) classification

121 system, with a few notable exceptions like nitrofurantoin.[14] Quantities were calculated as

122 number of dispensed packs per month, without making an attempt to estimate the amount of

123 defined daily doses contained in a pack. While this might lead to an over- or underestimation of

124 the true proportion of linkage if linkage depends on dosage, packs provided a fast option to

125 compare average linkage which can be easily extended to other classes of drugs.

126

127 All antibiotic dispenses in HTI falling within the study period were extracted using the above

128 definition. A quality control of the extract was performed, assessing it for clinically unlikely

129 outliers due to data entry errors. Three antibiotic agents, ceftadizime, colistin, and

130 sulfamethoxypyridazine, were excluded from the analysis, as some hospitals were found to

131 report number of tablets dispensed instead of number of packs in a considerable number of

132 cases. For other included antibiotics, the number of matching identifiers used for linkage was

133 examined.

134

135 Dispensing was then aggregated and compared to quantities reported in HPA for the same set

136 of hospitals. The overall proportion of antibiotics that could be linked to a patient was estimated

137 as the percentage of HPA dispensing found in HTI and appropriate 95%-confidence intervals

138 (CI) were calculated using bootstrapping with 2,000 samples. Linkage was stratified by form,

139 therapeutic agent and ward. Drugs were classified as oral, intravenous or another form (topical,

140 lung administration, rectal, etc.) using EphMRA's New Form Code. Antibiotic agents were

141 grouped by antibiotic class and changes in linkage of these classes were compared over time.

142 Dispensing was stratified by the five ward specialties with the highest observed usage in HPA:

143 Accidents & Emergencies (A&E), general medicine, geriatrics, intensive care and respiratory

144 medicine (thoracic medicine and respiratory clinics). Finally, linkage of individual antibiotic

145 agents was contrasted across wards, using drugs indicated for methicillin-resistant

146 *Staphylococcus aureus* (MRSA) infections by the British National Formulary as an example.

147

148 Approval for this study was obtained by the Clinical Practice Research Datalink's Independent

149 Scientific Advisory Committee for MHRA database research (ISAC) as part of the protocol

150 16/102.

151

152 All analyses were carried out using R software version 3.3.1 for Windows.[15]

153

154 **Results**

155

156 On average, 27.6% (CI: 27.4% - 27.8%) of all antibiotics dispensed in hospitals contributing to

157 HTI could be linked to an individual patient (Table 1). The general strength of linkage was high,

158 with more than 85% of the linkage based on NHS number and one or more additional identifiers

159 (see Supplement Table 1).

160

161 The proportion of packs linked to a patient depended on the form of the drug, the antibiotic

162 agent and the type of ward. Respiratory medicine and geriatrics had an above average linkage

163 of 48.3% (CI: 47.2% - 49.8%) and 39.6% (CI: 38.9% - 40.6%) respectively (Table 1).

164 Emergency departments had much lower linkage of antibiotics, with 4.4% (CI: 4.3% - 4.4%) of

165 dispensed antibiotics recorded in intensive care and 8.7% (CI: 8.7%- 8.7%) recorded in A&E.

166 Linkage for general medicine was 13.2% (CI: 12.9% - 13.7%). Together, these five ward

167 specialties were responsible for almost half of all antibiotic dispensing in the study period.

168 Among other wards, exceptionally high linkage across all antibiotics was found in radiotherapy

169 (89.0%, CI: 88.1% - 89.9%), whereas only 0.4% (CI: 0.4% - 0.4%) of antibiotics used in

170 operating theatres were recorded.

171

172 Oral antibiotics had a linkage of 37.2% (CI: 37.1% - 37.3%) while intravenous dispensing,

173 accounting for almost two thirds of all antibiotic dispensing in hospitals, was less well captured

174 with 21.9% (CI: 21.6% - 22.2%) linked to a patient. The highest linkage was achieved in other

175 forms of antibiotics, but those only accounted for a small fraction of all dispenses.

176

177 Regarding antibiotic groups, quinolones and carbapenems were recorded best, with 546,721

178 (62.6%; CI: 61.8 % - 63.8%) respectively 278,668 (46.9%; CI: 46.6% - 47.2%) dispensed packs

179 covered. Of all tetracyclines dispensed in hospital, 35.9% (CI: 35.8%-36.1%) could be linked to

180 an individual patient. Cephalosporins and macrolides corresponded to the average with 391,553

181 (28.5%; CI: 28.2% - 28.8%) and 639,042 (27.2%; CI: 27.1% - 27.3%) packs recorded in HTI.

182 Penicillins could only be related to a patient for 21.1% (CI: 21.1% - 21.2%) of dispensed packs.

183 This is especially noteworthy, as penicillins accounted for half of all packs dispensed.

184 Furthermore, the proportion of penicillins observed in HTI decreased slightly over the study

185 period (see Supplement Figure 1). In contrast, linkage of carbapenems increased at the

186 beginning of 2013 from 44% to 52%. All other classes of antibiotics fluctuated around their initial

187 levels.

188

189 Looking into individual antibiotic agents, linkage ranged from 100.0% (CI: 74.1% - 100.0%) in

190 telavancin, 97.4% (CI: 96.3% - 98.5%) in lymecycline and 92.1% in both linezolid (CI: 91.2% -

191 93.0%) and moxifloxacin (CI: 90.7% - 93.5%) to 3% in cefuroxime (CI: 3.4% - 3.6%), gentamicin

192 (CI: 3.3% - 3.4%) and penicillin G (CI: 3.0% - 3.1%) (Table 2). Limiting dispensing to specific

193 wards influenced the proportion of linkage observed, as exemplified by the linkage of MRSA

194 drugs in intensive care, general medicine, geriatrics and respiratory wards (Table 3). Higher

195 proportions of linkage could be achieved for many drugs when looking solely at respiratory or

196 geriatric wards. Drugs dispensed on general medicine wards, on the other hand, had almost

197 consistently lower linkage than average.

198

199 **Discussion**

200

201 Linkage of antibiotic dispenses varied with individual antibiotic and ward settings. Overall, in HTI

202 a quarter of antibiotic dispensing was linked to an individual patient. Linkage of frequently used

203 treatments was low, probably due to the fact that these drugs are less likely to be prescribed

204 directly from pharmacy and often held as ward stock. As a consequence, coverage of high

205 usage antibiotics like gentamicin, broad-spectrum penicillins and vancomycin was limited.

206 Alternative treatments (e.g. clindamycin, daptomycin and tigecycline) had a much higher linkage

207 across wards. The achieved proportion of linkage varied considerably depending on the ward

208 where they were dispensed. Looking specifically at patients in wards like geriatrics or

209 respiratory medicine improved the proportion of treatment observed and in multiple cases

210 yielded linkage of more than 80%. Patterns of linkage changed little across the study period,

211 with the exception of a sudden increase in linkage of carbapenems at the start of 2013. It is

212 possible that the reductions in dispenses from ward stock represent the impact of stewardship

213 initiatives promoting judicious use of carbapenems.

214

215 This is the first study evaluating the representativeness and completeness of data recorded in

216 HTI for research on antibiotic usage. We were able to identify and describe major factors

217 influencing linkage of antibiotic treatment. However, the results of this study were limited in

218 some ways. First, linkage was compared based on the number of dispensed packs to provide

219 an easy methodology for estimating linkage quality. This approach may over- or underestimate

220 the true proportion of linkage if linkage depends on the number of daily doses contained in a

221 pack, e.g. if larger packs are less likely to be linked. If a study is to be performed on HTI, those

222 results should therefore only act as a first indicator of feasibility and should be followed up by a

223 detailed analysis based on daily doses. Second, the identity of the participating hospitals was

224 not available to researcher and no hospital identifiers existed in the database at the time of

225 study. Consequently, no statement could be made about variations in demographics or

226 dispensing behaviour between individual hospitals. It is possible that findings in this study

227 mainly reflect the effect of low antibiotic recording in a subset of hospitals. The inclusion of an

228 anonymous trust identifier might reveal a subset of hospitals with high quality data linkage (e.g.

229 due to local resistance patterns), which would allow investigating associations between drug

230 usage and indications in more detail. Trust identifiers will be added to the database with the

231 next data update in spring 2017. Finally, no evaluation of successful linkage could be

232 performed. Linkage was conducted by NHS Digital as a trusted third party and we had no

233 access to identifiable patient data. Consequently, no individual patient files could be revisited

234 and records were treated as correctly linked where linkage was observed. False linkage could

235 not be investigated in this study. If the linkage algorithm falsely mapped dispenses and patients

236 in a large proportion of cases the findings in this study would overestimate true linkage.

237

238 This study has highlighted some limitations, which must be taken into account for antibiotic

239 research using HTI as a data source. Further evaluation is needed on HTI for other therapeutic

240 agents with particular emphasis on the role of ward stock. Papers looking into the validity of

241 prescribing databases in primary care in England generally found a high conformity of the

242 quantity of drugs recorded when compared to external sources.[16,17] High coverage of drugs was

243 also found for a secondary care database in the Taiwanese insurance-based healthcare

244 system.[18] A study specifically investigating antibiotic prescribing in a Dutch secondary care

245 database was able to obtain treatment for all patients with community-acquired pneumonia,

246 although no validation of the obtained information was performed.[19] The comparably low linkage

247 found for some antibiotics in this study likely reflects a high use of ward stock dispensing for

248 antibiotic treatment in English hospitals[20] and a current inability to capture this dispensing. This

249 conclusion is supported by findings on determining factors for linkage of dispensed drugs.

250 Linkage was lowest across settings in which antibiotic usage tended to be either common or

251 urgent, as is the case in A&E and intensive care. These situations potentially favour a higher

252 utilisation of ward stock because of time constraints and efficiency gains. Linkage was generally

253 higher for drugs like carbapenems and quinolones, which are used more cautiously and have

254 been subject to increased stewardship measures over the last 15 years.[21] Yet, the high levels of

255 linkage in geriatrics and respiratory medicine, as compared to general medicine, cannot be fully

256 explained by these differences.

257

258 Although HTI in its current form does not seem to reflect a true picture of general antibiotic

259 dispensing in secondary care, therefore preventing it from being used for widespread antibiotic

260 surveillance, it has value for specific antibiotic research related to individual agents in specific

261 ward settings, and may be used for broader studies where the missing drug usage can be

262 estimated. There remains a pressing need for comprehensive and complete data to evaluate

263 the intended and unintended impacts of AMS programmes in hospitals. However, although

264 hospitals are clearly setting the course for e-prescribing,[22] full adoption and availability for

265 secondary use might still take years. For now, linking HES to pharmacy data provides a

266 potential mechanism to investigate some patient-level drug usage across NHS hospitals. We

267 have shown that this is already possible for a number of antibiotics, in particular in medical

268 settings that rely less on ward stocks. Using hospital identifiers within HTI to identify sites with

269 above-average linkage could be used to further improve coverage and to enable the analysis of

270 more common antibiotics in HTI. Finally, reducing the reliance on ward stock in hospitals in the

271 panel might be a way to continue increasing this linkage. The unexpected large differences in

272 linkage rates between closely related wards, seen for example in general medicine and

273 geriatrics, suggest that it is feasible to do so. Further research will be needed to understand and

274 learn from the systematic differences in these ward level processes, the results of which may

275 aid in elevating the status of antibiotics from drugs used in everyday medicine to a limited

276 resource that requires prudent management.

277

292

Author contributions

P.R. and L.S. developed the study protocol. P.R. performed the data extraction, analysis and

writing of the manuscript, supervised by L.S. D.A. and L.S. advised on the interpretation of the

study findings and revised the final manuscript.

297

Tables and Figures

Table 1 - Total number of antibiotics dispensed and proportion linked to an individual patient

	Total packs dispensed	Patient-linked packs		
		n	% of total	(95%-CI)
All	22,885,454	6,317,947	27.6	(27.4 – 27.8)
Dispensing ward				
Accident & Emergency	2,389,513	207,842	8.7	(8.7 – 8.7)
General Medicine	4,039,748	532,728	13.2	(12.9 – 13.7)
Geriatrics	1,364,470	540,037	39.6	(38.9 – 40.6)
Intensive Care	1,222,121	53,311	4.4	(4.3 – 4.4)
Respiratory Medicine	1,154,135	557,398	48.3	(47.2 – 49.8)
Other	12,715,467	4,426,631	34.8	(34.5 – 35.1)
Form				
Intravenous	14,358,600	3,144,292	21.9	(21.6 – 22.2)
Oral	8,518,627	3,169,344	37.2	(37.1 – 37.3)
Other	8,227	4,311	52.4	(51.3 – 53.7)
Antibiotic class				
Carbapenems	594,394	278,668	46.9	(46.6 – 47.2)
Cephalosporins	1,376,450	391,553	28.4	(28.2 – 28.8)
Macrolides	2,351,805	639,042	27.2	(27.1 – 27.3)
Penicillins	12,026,953	2,538,705	21.1	(21.1 – 21.2)
Quinolones	873,831	546,721	62.6	(61.8 – 63.8)
Tetracyclines	575,250	206,723	35.9	(35.8 – 36.1)
Others	5,086,771	1,716,535	33.7	(32.9 – 34.6)

**Table 2 - Linkage of individual antibiotic agents in HTI (Apr 2011 – Mar 2015)**

	Total packs (as recorded in HPA)	Patient – linked packs	
		n	% of total
Amikacin	44,119	19,569	44.35
Amoxicillin	1,552,520	323,235	20.82
Amoxicillin/Clavulanic Acid	2,318,864	595,729	25.69
Ampicillin	516	103	19.92
Ampicillin/Flucloxacillin	4,183	547	13.07
Azithromycin	514,125	177,580	34.54
Aztreonam	96,205	64,953	67.52
Cefaclor	19,125	10,723	56.07
Cefadroxil	1,751	676	38.60
Cefalexin	280,941	100,843	35.89
Cefixime	4,661	2,402	51.53
Cefotaxime	179,128	29,663	16.56
Cefpodoxime Proxetil	18	6	32.79
Cefradine	17,945	7,103	39.58
Ceftaroline Fosamil	70	41	59.40
Ceftriaxone	506,527	226,346	44.69
Cefuroxime	364,476	12,597	3.46
Cefuroxime Axetil	1,806	1,152	63.77
Chloramphenicol	154,784	91,252	58.95
Cilastatin/Imipenem	46,884	12,082	25.77
Ciprofloxacin	613,061	400,300	65.30
Clarithromycin	1,575,692	370,088	23.49
Clindamycin	378,721	233,180	61.57
Dalfopristin/Quinupristin	89	85	95.14
Daptomycin	55,118	47,221	85.67
Demeclocycline	11,098	7,077	63.76
Doripenem	0	0	–
Doxycycline	518,694	159,485	30.75
Ertapenem	246,339	137,143	55.67
Erythromycin	262,324	91,374	34.83
Flucloxacillin	1,546,681	382,220	24.71
Fosfomycin	416	147	35.20
Fusidic Acid	22,131	18,470	83.46
Gentamicin	916,173	30,513	3.33
Levofloxacin	165,184	82,624	50.02
Linezolid	28,520	26,267	92.10
Lymecycline	16,042	15,623	97.39
Meropenem	301,170	129,442	42.98
Minocycline	3,494	3,120	89.31
Moxifloxacin	54,147	49,883	92.12
Neomycin	9	8	92.38
Norfloxacin	1,015	887	87.47
Ofloxacin	40,424	13,026	32.22

Oxytetracycline	13,919	12,410	89.16
Penicillin G	186,962	5,663	3.03
Penicillin V	553,564	179,302	32.39
Piperacillin	0	0	–
Piperacillin/Tazobactam	5,782,414	1,000,979	17.31
Pivmecillinam	11,523	8,386	72.77
Polymethyl M	460	0	0.00
Rifabutin	1,777	1,395	78.54
Sulfadiazine	1,896	1,414	74.58
Sulfamethizole/Trimethoprim	633	217	34.27
Sulfamethoxazole/Trimethoprim	170,395	106,382	62.43
Teicoplanin	1,313,907	532,186	40.50
Telavancin	27	27	100.00
Temocillin	41,666	30,849	74.04
Tetracycline	2,110	1,824	86.44
Ticarcillin/Clavulanic Acid	28,060	11,694	41.67
Tigecycline	9,894	7,184	72.61
Tobramycin	136,028	86,051	63.26
Trimethoprim	637,583	164,564	25.81
Vancomycin	1,127,444	292,635	25.96

Table 3 - Differences in linkage of antibiotics used to treat methicillin resistant staphylococcus aureus infections

	All wards n % (95%-CI)	General medicine n % (95%-CI)	Geriatrics n % (95%-CI)	Respiratory n % (95%-CI)
Teicoplanin	532,186 40.5 (40.2 – 40.8)	43,464 24.0 (23.5 – 24.5)	38,142 65.5 (64.2 – 66.7)	14,994 71.5 (69.1 – 74.0)
Vancomycin	292,635 26.0 (25.8 – 26.1)	31,388 18.9 (18.5 – 19.3)	37,653 50.4 (49.5 – 51.2)	14,746 36.1 (35.2 – 37.1)
Clindamycin	233,180 61.6 (61.2 – 61.9)	19,391 37.1 (36.5 – 37.7)	11,899 68.5 (67.0 – 69.9)	8,465 79.9 (77.9 – 82.0)
Daptomycin	47,221 85.7 (84.1 – 87.1)	2,602 40.2 (38.0 – 42.5)	1,977 80.4 (75.5 – 85.6)	2,367 99.3 (92.9 – 100.0)
Linezolid	26,267 92.1 (91.2 – 93.0)	1,587 60.4 (58.4 – 62.4)	1,297 72.4 (69.7 – 75.1)	1,884 80.0 (77.2 – 82.8)
Fusidic acid	18,470 83.5 (81.7 – 85.3)	1,147 55.7 (51.9 – 59.7)	1,011 61.2 (57.7 – 64.4)	792 78.4 (70.1 – 86.9)
Tigecycline	7,184 72.6 (71.8 – 73.5)	798 52.9 (51.4 – 54.4)	370 71.7 (68.9 – 74.5)	487 65.2 (62.5 – 68.1)
Ceftaroline	41 59.4 (51.4 – 68.0)	10 85.5 (85.5 – 85.5)	0 –	0 –
Telavancin	27 100.0 (74.1 – 100.0)	0 –	0 –	0 –

Figure 1 – Schematic structure and source of inpatient data and antibiotic dispenses in Hospital Treatment Insights
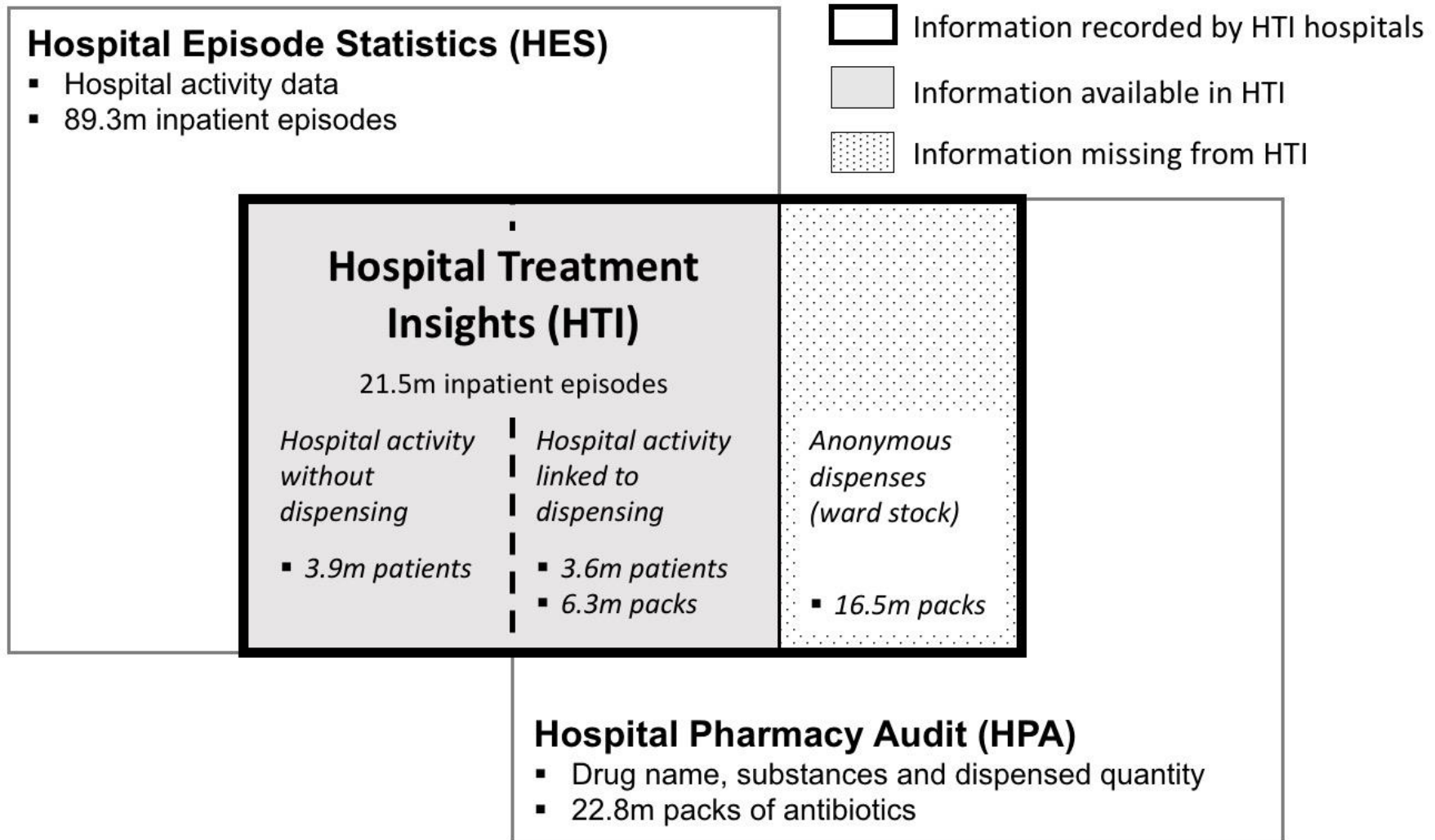
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