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1 **A qualitative process evaluation of the introduction of procalcitonin testing as an**
2 **antimicrobial stewardship intervention.**

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10 **Abstract**

11 Background

12 Successful antimicrobial stewardship interventions are imperative in today's environment of
13 antimicrobial resistance. New antimicrobial stewardship interventions should include
14 qualitative analysis such as a process evaluation to determine which elements within an
15 intervention are effective and provide insight into the context in which the intervention is
16 introduced.

17 Objective

18 To assess the implementation process and explore the contextual factors which influenced
19 implementation.

20 Setting

21 An academic teaching hospital in Cork, Ireland.

22 Methods

23 A process evaluation was conducted on completion of a feasibility study of the introduction
24 of a procalcitonin antimicrobial stewardship intervention. The process evaluation consisted
25 of semi-structured face-to-face interviews of key stakeholders including participating
26 (senior) doctors (5), medical laboratory scientists (3) and a hospital administrator. The
27 Consolidated Framework for Implementation Research was used to guide data collection,
28 analysis, and interpretation.

29 Main outcome measures

30 Qualitative assessment of the intervention implementation process, the contextual factors
31 which influenced implementation and identification of improvements to the intervention
32 and its implementation and determine if proceeding to a randomised controlled trial would
33 be appropriate.

34 Results

35 Analysis of the interviews identified three main themes. (i) The procalcitonin intervention
36 and implementation process was viewed positively to support prescribing decisions.

37 Participants identified modifications to procalcitonin processing and availability to improve
38 implementation and allow procalcitonin to be "*more of a clinical influence*".

39 ii) In the antimicrobial stewardship context the concept of fear of missing an infection and
40 risks of potentially serious outcomes for patients emerged.

41 (iii)The hospital context consisted of barriers such as available resources and facilitators
42 including the hospital culture of quality improvement.

43 Conclusion

44 This process evaluation provides a detailed analysis of the implementation of procalcitonin
45 testing as an antimicrobial stewardship intervention. The positive findings of this process
46 evaluation and feasibility study should be built upon and a full randomised controlled trial
47 and economic evaluation should be conducted in a variety of hospital settings to confirm the
48 effectiveness of procalcitonin as an antimicrobial stewardship intervention.

49 **Impact on practice**

- 50
- Procalcitonin is a useful additional antimicrobial stewardship intervention
 - The fear of missing infections and the risk of negative clinical outcomes for patients
51 significantly influences antimicrobial prescribing decisions and must be considered
52 when designing antimicrobial stewardship interventions.
 - A culture of quality improvement within a hospital is an important facilitator of
53 antimicrobial stewardship programmes
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| 57 | Keywords |
| 58 | Antimicrobial stewardship |
| 59 | Respiratory tract infections |
| 60 | Procalcitonin |
| 61 | Process evaluation |
| 62 | Consolidated Framework for Implementation Research |

63 Introduction

64 Antimicrobial resistance(AMR) is a significant risk to human health and we face the very real
65 possibility of a “post antibiotic era in which common infections could once again kill”[1].
66 Antimicrobial stewardship(AMS) programmes are well established and include interventions
67 to improve antimicrobial prescribing[2-4]. Some AMS interventions can lack sustainability[5]
68 which may be related to contextual factors of those interventions, but these have been poorly
69 investigated particularly their role in the effectiveness of interventions and sustainability on
70 a larger scale[6]. This has prompted the suggestion that interventions should look to include
71 components that enhance enablement for the implementation of evidence-based practice,[6]
72 defined as *“increasing means or reducing barriers to increase capability or opportunity”*[6, 7].
73 Furthermore a recent Cochrane review of interventions to improve antimicrobial prescribing
74 for hospital patients[8] has advocated for greater use of qualitative research such as a process
75 evaluation(PE) of a trial to determine which elements within an intervention are effective.
76 A qualitative PE[9] assesses the fidelity and quality of implementation, providing insight into
77 the context into which the intervention is introduced, clarifies causal mechanisms of the
78 intervention without assuming that the intervention itself leads to the outcome and builds
79 the evidence base to support the intervention that will inform policy makers and practice[10].
80 A PE is important in complex interventions in the healthcare setting as a means to identify the
81 underlying cause of the success or failure of interventions because occasionally even highly
82 successful quality improvement interventions[11] have proven difficult to replicate in
83 different contexts due to fundamental differences in how the intervention was delivered[12].
84 A PE is an important element of implementation research and should incorporate a
85 theoretical framework to guide data collection, analysis and interpretation. Theoretical
86 frameworks have a predictive capacity to identify or explain causal mechanisms of

87 implementation. This allows for identification of contextual factors that influenced
88 implementation and so aids our ability to generalise study findings.[13].

89 Greater utilisation of rapid diagnostic tests and biomarkers has been highlighted as an
90 important factor in addressing AMR by improving infection diagnosis, supporting prescribing
91 decisions and AMS programmes[14]. Procalcitonin is a biomarker which has been shown to
92 support prescribing decisions and reduce antimicrobial use safely in patients with respiratory
93 tract infections[15-18]. The findings of a recent Cochrane review[17] supports its use in the
94 context of AMS in safely reducing antimicrobial consumption by 2.4 days in patients with
95 respiratory tract infections. We have previously reported the positive influence of
96 procalcitonin on antimicrobial prescribing following the introduction of procalcitonin testing
97 in a feasibility study[19]. The study identified some variability in the use and interpretation of
98 procalcitonin levels suggesting a range of factors influenced implementation and should be
99 explored to improve the effectiveness of intervention implementation in the future.

100 Feasibility studies should be complemented by a qualitative PE[9] to facilitate improved
101 development and implementation of interventions[20]. This is particularly relevant when
102 introducing new diagnostic tests to support AMS to assess how best to use such new tests[21]
103 and reporting of qualitative analysis of procalcitonin implementation has been limited[22,
104 23].

105 **Aim of the study**

106 To explore how and why the introduction of a procalcitonin intervention worked or did not
107 work in an Irish hospital setting. The study objectives were to gain an understanding and
108 assessment of the fidelity and quality of the implementation process, explore the contextual
109 factors which influenced implementation, identify the barriers and facilitators to

110 implementation and inform improvements to the intervention and its implementation if
111 proceeding to a randomised controlled trial was deemed appropriate.

112 **Ethics**

113 The study was approved by the Clinical Research Ethics Committee of University College Cork
114 and the Cork Teaching Hospitals (reference code ECM 4 (w) and ECM 3 (III)). Written informed
115 consent was obtained from all participants prior to the interviews and confidentiality of the
116 participants was assured.

117 **Methods**

118 The Standards for Reporting Qualitative Research were used to guide the development of
119 this manuscript[24].

120 A qualitative PE was conducted of a single centre, randomised, open-label feasibility study[19]
121 of the introduction of procalcitonin testing in patients admitted to hospital with a lower
122 respiratory tract infection, under the care of the respiratory medicine team, during on-call
123 acute unselected general medical take. The feasibility study ran from June 1st 2017 to May
124 31st 2018 and was conducted in a single, 321 bed model 3 (smaller general)[25] inner city,
125 voluntary acute University Teaching Hospital, which is part of the South/South West Hospital
126 Group[26] in the Republic of Ireland. The PE was conducted following completion of the
127 feasibility study.

128 The Consolidated Framework for Implementation Research(CFIR) [27] was used to guide data
129 collection, analysis, and interpretation. It is a meta-theoretical framework based on existing
130 determinant frameworks and multiple implementation theories which provides a roadmap of
131 constructs to monitor the implementation process[27] by recognising that implementation is
132 a multidimensional phenomenon with multiple interacting influences from the individual to
133 the organisation and beyond[28]. The CFIR was chosen because it can be applied at any stage

134 of the evaluation process of an intervention, it provides a framework to investigate and assess
135 the complex multi-level nature of implementation in the healthcare setting including barriers
136 and facilitators to effective intervention implementation[13] and provides a way in which to
137 organise and communicate findings.

138 **Participants**

139 An invitation to participate in the study was issued in person or by email to key stakeholders
140 involved in the feasibility study or would be involved in the decision to implement
141 procalcitonin testing in the hospital in the future. All agreed to participate but one medical
142 doctor later withdrew due to scheduling constraints. Participants included five medical
143 doctors (DR1-5) (3 respiratory clinicians and 2 general clinicians), three medical laboratory
144 scientists (MS1-3) and a hospital administrator (ADM). The interviews ranged in length from
145 6 to 29 minutes with a mean duration of 16 minutes.

146 **Data collection**

147 Semi-structured face-to-face interviews were conducted by the primary researcher.
148 Interviews took places in the hospital where the study was conducted at a date and time that
149 was convenient for participants. The interview topic guide was developed by two researchers
150 (FOR and AF), both pharmacists with experience of AMS. The interview topic guide was
151 informed by the most relevant CFIR constructs[27] which were used as a 'check-list' of
152 variables for consideration. The topic guide was refined following a pilot interview with a
153 medical doctor who participated in the feasibility study. Pilot interview data were included in
154 the study due to the limited number of medical doctors participating directly in the feasibility
155 study.

156 Interviews with medical laboratory scientists focused on the provision of procalcitonin testing
157 in the laboratory, the interviews with doctors focused on the use of procalcitonin in making

158 antimicrobial prescribing decisions while the interviews of participants with managerial
159 responsibilities and the hospital administrator focused on implementation of procalcitonin
160 testing on a larger, ongoing scale in the hospital. Issues and opinions on AMS and the hospital
161 context for change and quality improvement were asked of all participants.

162 All interviews were digitally recorded and transcribed verbatim by a professional transcription
163 service. The accuracy and quality of the transcripts was checked against the original
164 recordings and any identifiable data was removed from the transcripts (by FOR).

165 **Data analysis**

166 Interview analysis used the framework method[29, 30] which provides a systematic step-wise
167 approach to produce structured outputs of summarised data and is most commonly used for
168 the thematic analysis of semi-structured interview transcripts[29]. It consists of the following
169 steps 1. Transcription of the interviews, 2. Familiarisation with the interview data 3. Coding
170 of the data using the CFIR constructs as deductive codes (open coding was applied when
171 themes emerged during the familiarisation process that did not fit within the definitions of
172 the CFIR constructs) 4. Charting and indexing of the data using a thematic framework 5.
173 Interpretation and analysis of the data.

174 The interview transcripts were coded independently by two researchers (FOR and AF) using
175 the CFIR constructs and open coding by thematic analysis. All 39 constructs of the CFIR were
176 used as the a priori codebook for this qualitative study. Important domains and constructs
177 were identified based on the frequency of their appearance in the interviews, the degree of
178 importance articulated by the participants or the researchers, or both. Emergent themes
179 were reviewed throughout the interview process and the team made an assessment as to
180 when data saturation had occurred. All authors reviewed the final codes. Discrepancies were
181 resolved through discussion.

182 **Results**

183 Nine interviews were conducted with hospital staff to explore the different aspects of the
184 procalcitonin intervention implementation in the hospital setting. Participants roles in
185 implementation are contained in Table 1 below. The results have been informed by the CFIR
186 and are categorised into three themes. 1. The procalcitonin intervention and the
187 implementation process, 2. The AMS/AMR context and 3. The hospital/organisational
188 context. Within these themes participants described a range of factors that interact with each
189 other and the intervention to produce an effect as a facilitator or barrier to implementation.
190 The CFIR constructs identified in the themes are listed in Table 2 below. They are supported
191 by qualitative excerpts from the interviews (Tables S1, S2 and S3 available as supplementary
192 data). The constructs of the CFIR are highlighted in bold in the text.

193 **Theme 1: Procalcitonin intervention and implementation process**

194 Participants described the procalcitonin intervention as having a well-established evidence
195 base to support its use and clinical situations where it could act as an “*extra marker*” to
196 support antimicrobial prescribing decisions. These decisions require clinicians to balance the
197 need to adequately treat patients while also safely minimising antibiotic exposure and is a
198 situation where “*procalcitonin would actually play a very useful role.*” The feasibility study
199 design and accompanying PE aligned with the **trialability** construct by providing participants
200 the opportunity to test procalcitonin on a smaller scale, develop experience, reflect on the
201 intervention, suggest changes to improve the intervention and adaptation in the future.
202 Participants provided specific examples of clinical situations where procalcitonin supported
203 antimicrobial prescribing decisions along with examples of where it was considered of less
204 benefit. Overall participants felt more confident in the role of procalcitonin in the acute

205 infective setting and less confident in the reliability of procalcitonin in patients with
206 underlying chronic lung disease. (Indicative quotations are shown in Table S1)

207 Several elements of the '**adaptable periphery**' [27] emerged which could be modified to
208 improve the processing of samples in the laboratory and the subsequent availability of the
209 procalcitonin results to clinicians. They included processing of the test more efficiently as part
210 of a patients biochemistry profile by the biochemistry laboratory rather than processing
211 samples in the microbiology laboratory (which occurred in this study). This would facilitate
212 more prompt availability of results as part of the standard admission point of care blood test
213 results. The changes suggested to the laboratory processing of the results were due to the
214 elements of the intervention which aligned to the **complexity** construct and were considered
215 barriers to implementation. (Indicative quotations are shown in Table S1)

216 Participants commented positively on the education and training provided and were engaged
217 with the intervention and its intended purpose of improving antimicrobial prescribing.
218 (Indicative quotations are shown in Table S1)

219 Participants suggested several other general recommendations to facilitate implementation
220 of procalcitonin testing which aligned to the **reflecting and evaluation** construct. They
221 included recommendations for a "*multi-modal*" educational plan, the need to identify the role
222 of procalcitonin, "*it's place in the hierarchy*" and to consider potential unintended
223 consequences of its use. Participants also highlighted the need to gain support and
224 endorsement from hospital management and senior clinicians and using public forums within
225 the hospital such as "*grand rounds*" to facilitate this objective and engage **champions**
226 (individuals) who actively associate themselves to support the intervention during
227 implementation.

228 Several potential barriers to implementation were also identified by participants. One
229 participant highlighted that procalcitonin *“has been around for quite some time”* and
230 questioned its **relative advantage** over C—reactive protein as an indicator of viral infections.
231 The barrier of additional costs and availability of resources to support new interventions in
232 the hospital means they would require *“a really strong business case to suggest why we
233 should add a resource”*. The **opportunity cost** associated with implementing a procalcitonin
234 intervention was also raised with the suggestion that alternative AMS interventions may be a
235 more beneficial use of resources but this would require an economic assessment to
236 determine the most cost-effective intervention..

237 The respiratory specialist participants in the study expressed a strong sense of **self-efficacy**
238 and confidence in their professional knowledge and clinical experience of treating respiratory
239 tract infections and making antimicrobial prescribing decisions *“it’s very much linked to what
240 we do”*. They highlighted situations where they have come into conflict with the AMS team in
241 relation to compliance with antimicrobial guidelines highlighting they *“don’t inappropriately
242 apply the guidelines as opposed to that we ignore them”*. These findings were considered a
243 potential barrier to implementation of AMS interventions.

244 **Theme 2: Antimicrobial stewardship and antimicrobial resistance context**

245 The need to address the problems associated with AMR were seen as facilitators to AMS
246 interventions. Patient safety was seen as a priority but participants highlighted the increasing
247 complexity and difficulties in managing patients with resistant infections. The management
248 of patients with carbapenemase producing *Enterobacteriaceae* emerged as an example of the
249 organisational approach to the problem of AMR and elements of this approach were
250 considered as facilitators of implementation. The hospital *“eventually”* realised the problems
251 associated with carbapenemase producing *Enterobacteriaceae* following communication

252 between national and local level management resulting in greater **leadership engagement** at
253 local level to address the problem. These factors created a **tension for change** to respond to
254 this problem within the organisation and the need to take a long term rather than a short
255 term view to respond to the problem. (Indicative quotations are shown in Table S2)

256 The **culture** within the hospital in relation to antimicrobial prescribing emerged as a barrier
257 to implementation of AMS interventions. The concepts of fear and risk aversion were a
258 significant influence on antimicrobial prescribing decisions. Fear arose in relation to the
259 *“possibility of missing infection”* in patients and the associated potential for negative clinical
260 outcomes for those patients related to an inadequately treated infection and the associated
261 feelings of clinical responsibility (indicative quotations are shown in Table S2). This fear was
262 accompanied by the *“fear of litigious issues”* and the need for *“self-protection”*. Clinicians
263 described the risk-aversion and need for self-protection as motivating factors for the
264 prescription of antimicrobial courses to patients *“even in times that maybe the front-line
265 clinician themselves maybe isn’t convinced fully that it’s a bacterial infection”*. There was
266 acknowledgement of antimicrobial over-prescribing but these risks were outweighed by the
267 needs of the individual complex sick patient admitted to hospital. A possible explanation for
268 this which emerged was that the longer term consequences of AMR *“aren’t as apparent”* and
269 may be perceived to be less important than the treatment of current patients. There was also
270 an acknowledgement that the problem requires a significant amount of behavioural change
271 as the *“habits of the prescribing hand are firm and hard to change”*.

272 **Theme 3: Hospital/organisational context**

273 All participants described a range of factors which act as barriers or facilitators of
274 implementation. A growing culture of quality improvement in the hospital was described by
275 all participants aligning with the **culture** construct. There were some differing individual

276 perspectives on the degree of **leadership engagement** with quality improvement in the
277 hospital with an acknowledgement that senior clinicians could be more engaged with it. The
278 development of structural *“scaffolding”* to support a clinical lead with dedicated time to
279 encourage and support quality improvement work was identified as a facilitator of future
280 interventions. (Indicative quotations are shown in Table S3)

281 Communication was seen as an important facilitator of interventions aligning with the
282 **networks and communication** construct. The hospital size was seen as a positive factor to
283 encourage greater engagement with colleagues. Communication between medical teams and
284 the AMS team was seen as good and had a positive influence on antimicrobial prescribing.
285 However inter-departmental communication, and communication between senior clinicians
286 and hospital management emerged as a barrier to implementation. (Indicative quotations are
287 shown in Table S3)

288 **Available resources** emerged as a barrier to implementation in relation to the limitations of
289 the funding model of Irish healthcare where despite the intensions of staff there is limited
290 opportunities to *“invest to get future success”*. Participants also raised issues related to the
291 perception of how resources are distributed within the hospital *“it does seem to be he who*
292 *shouts loudest”*.

293 **Discussion**

294 This study provides a detailed PE of the introduction of procalcitonin testing as an AMS
295 intervention. The CFIR guided a systematic assessment of the intervention and
296 implementation process, identification of barriers and facilitators of implementation, and
297 provided an insight into the contextual factors which influence AMS in the Irish hospital
298 setting. The findings provide actionable recommendations to successfully implement a
299 procalcitonin intervention.

300 The main findings of this study identified the positive elements of the intervention and
301 implementation process while also exploring the barriers to implementation related to the
302 intervention and the contextual barriers of the study setting to be overcome to successfully
303 implement a procalcitonin intervention. Participants engaged with the intervention, the
304 education provided, assessed the supporting evidence for the intervention, gained
305 experience of the intervention, reflected on its clinical value and proposed modifications to
306 the intervention delivery which would improve implementation in a future randomised
307 controlled trial. All these elements promote successful adaptation of interventions[27] and it
308 has also been shown that previous experience of procalcitonin testing leads to greater
309 confidence in the application of procalcitonin as an AMS intervention[31].

310 The adaptability and trialability constructs identified the most relevant factors to improve the
311 delivery and selection of patients to maximise the benefits of the intervention. Procalcitonin
312 levels were tested in the microbiology laboratory during this study and while the test itself
313 was relatively quick to process there were several factors which led to delays in the availability
314 of the results. These delays in availability resulted in clinicians feeling that *“hearing*
315 *afterwards it was something that you know, you felt almost it was a feedback after the*
316 *decision had been made”* rather than contributing to the clinical decision-making process.

317 Processing of the procalcitonin level in the biochemistry laboratory emerged as a solution to
318 this problem and the procalcitonin levels should be available as part of the admission list of
319 blood results at the point of care to allow the results to be *“more of a clinical influence”* on
320 prescribing.

321 The participating respiratory clinicians expressed a strong degree of self-efficacy in relation
322 to their expert knowledge and clinical experience in treating respiratory tract infections while
323 also acknowledging the diagnostic difficulties associated with respiratory tract infections.
324 These findings suggest that respiratory clinicians could be perceived as barriers to
325 implementation of AMS interventions and are similar to those found in a recent study which
326 highlighted the barriers to integrating AMS processes within respiratory medicine[32]. The
327 perception that unsolicited AMS input is considered an imposition on specialist territory and
328 clinical autonomy among some medical specialists who consider themselves ‘experts in their
329 own fields’ is a considerable barrier to AMS interventions[33].

330 One clinician highlighted that procalcitonin *“has been around for quite some time”* and
331 questioned its relative advantage over other infection markers. However most participants
332 viewed the intervention positively which suggests that procalcitonin is a potentially effective
333 intervention as it combines clinician enablement, improved diagnostics to support AMS but
334 requires engagement with clinicians to optimise effectiveness. An intervention of this nature
335 would fulfil the recommendations of a recent study[34] to overcome barriers in AMS in
336 respiratory medicine. These findings align with a qualitative study of clinicians experience
337 with procalcitonin where the intervention was viewed positively as an AMS adjunct but it
338 could not replace other tests or clinical judgement[35].

339 The CFIR provided a framework to explore the two main contextual factors of AMS and the
340 hospital/organisational context into which the intervention was introduced. Contextual

341 factors influencing AMS interventions have been poorly explored in the past[6] and a lack of
342 understanding of the contextual factors contributing to a given problem can lead to sub-
343 optimal implementation[36].

344 The concepts of fear and risk-aversion were prominent themes in the AMS/AMR context. The
345 care of their patients and patient safety is the primary concern for clinicians[37]. Patients
346 admitted to hospital with a suspected infection are perceived to be more “*complex*” and
347 “*sick*” which heightens the fear of missing an infection and the potentially serious outcomes
348 for patients including death which heavily influences antimicrobial prescribing decisions. Fear
349 of adverse clinical outcomes especially in hospital patients has a powerful influence on
350 antimicrobial prescribing which can escalate the risk perception of clinicians[33]. Clinicians
351 were risk-averse even in situations where the risk of a bacterial infection is low “*I think a lot*
352 *of people will still cover with antibiotics*”. Clinicians also cited concerns on a personnel level
353 perceiving a need for self-protection and a fear of litigation which results in the prescription
354 of antimicrobials “*just in case*”. Justification of the fear of litigation may be due to the fact
355 that medical negligence suits filed in the Irish High court have increased by 136% from 2007
356 and 2018[38] and clinical negligence claims against the NHS in the UK have doubled over a
357 similar period[39]. In the ever-increasing litigious world we live in, this is a significant barrier
358 going forward.

359 The findings demonstrate that clinicians consider the short terms risks to patients and
360 themselves more heavily than the longer term consequences of AMR which “*aren’t as*
361 *apparent*” when making antimicrobial prescribing decisions similar to the findings of a recent
362 systematic review[40]. Risk, real or perceived, is challenging to mitigate against. AMS
363 programmes must acknowledge the experiences of risk faced by clinicians when designing
364 AMS interventions. An intervention such as procalcitonin acting as an “*extra marker*” of the

365 infection process offers clinicians further information when making antimicrobial prescribing
366 decisions potentially reducing the perceived risks for both patient and clinician.

367 The hospital context consisted of both barriers and facilitators to implementation. The
368 hospital administrator highlighted the recognition of the problems associated with AMR
369 having gained greater insight during the hospitals response to a carbapenemase producing
370 *Enterobacteriaceae* outbreak and the significant costs associated with it. Unfortunately the
371 realities of managing limited resources in a hospital environment where the short term
372 demands of trying to *“push people through the system”* is difficult and limits the ability of
373 hospitals to invest in new interventions or diagnostics to mitigate the long-term
374 consequences of AMR. These findings are similar to the findings of another study investigating
375 the perspective of hospital managers on optimising antimicrobial use[41]. A medical
376 laboratory scientist expressed frustration with the economic constraints of the healthcare
377 system where it appears that resources are allocated to *“he who shouts loudest”*. In the
378 current setting of a resource limited health service new interventions such as procalcitonin
379 must be supported by *“a really strong business case”* and an economic evaluation of the
380 intervention should be incorporated into a future trial particularly in the Irish hospital setting.
381 Procalcitonin testing has been shown to be a cost-effective AMS intervention in the U.S.
382 setting[42] but the overuse of procalcitonin testing has also been highlighted[43]. Long term
383 investment in the health system is necessary to alter the realities of AMR. This is particularly
384 important given our current population demographic in Ireland where the proportion of the
385 population over 65 years is expected to increase to 1.6 million in the next 35 years[44].

386 Positive findings from the hospital context included the recognition of developing a culture
387 of quality improvement in the hospital. Additional resources and support are required to
388 develop the *“scaffolding”* within the hospital but this is an important facilitator for the

389 development of new interventions. We know from previous work that organisations which
390 have a patient centred culture are more likely to implement change effectively[45].
391 Communications within an organisation has been recognised as being important in
392 intervention implementation. There was some variation in the assessment of it in the hospital
393 context and both positive and negative aspects were identified. The small size of the hospital
394 was noted as having a beneficial effect on communication in this study. Implementation has
395 been described as a 'social process' which is intertwined with the context in which it takes
396 place[46]. The importance of factors such as gaining "*consultant buy-in*" and using
397 educational forums such as grand rounds to encourage engagement and discussion of
398 interventions by senior clinicians are noted.

399 Strengths and limitations

400 The findings of this study and our earlier quantitative work[19] support the finding that
401 procalcitonin is an effective intervention and thus support the recommendations to link the
402 CFIR constructs to intervention outcomes[13]. We have outlined the justification for our
403 choice of the CFIR[13]. The study included a broad range of participants not just those directly
404 involved in the study implementation.

405 The study had several limitations. The study took place in a single hospital setting and
406 contextual influences may differ in other hospitals and this may limit its transferability.
407 However, as this is a feasibility study, this could not be mitigated for in this instance. Only one
408 hospital administrator was interviewed which limits the insight from the administrative
409 perspective on the hospital context. However due to the single study site it was only possible
410 to interview one administrator who would have the knowledge to provide these details. The
411 feasibility study and PE were conducted by the same researchers increasing the risk of positive
412 reporting. There was also a risk of the hawthorn effect during the data collection process as

413 it is possible the interviewer could have influenced the way people behave or respond. Efforts
414 to avoid or minimise bias and the Hawthorn effect included purposive sampling and inclusion
415 of a diverse sample of individuals.

416 **Conclusion**

417 This PE provides a detailed qualitative analysis of the implementation of procalcitonin testing
418 as an AMS intervention. Positive elements of intervention implementation were highlighted
419 along with modifications to improve the delivery of the intervention such as the prompt
420 availability of procalcitonin levels at the point of care to allow the test to be “*more of a clinical*
421 *influence*” on prescribing. Contextual factors which influence implementation were identified
422 and explored including the concepts of fear, risk and the influence of respiratory clinicians on
423 AMS interventions. We would recommend that the positive findings of this PE and feasibility
424 study should be built upon and that a full randomised controlled trial and economic
425 evaluation should be conducted in a variety of hospital settings to confirm the effectiveness
426 of procalcitonin as an AMS intervention.

427

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429

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435 **Conflict of interest**

436 There were no conflicts of interest to declare

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556 **Table 1.** Health professionals` role during the procalcitonin implementation

| Health professional | Role in implementation |
|-------------------------------|--|
| Hospital administrator | Hospital-wide managerial responsibilities and oversight of funding decisions |
| Respiratory clinicians | Involved in the procalcitonin intervention implementation and assessment |
| Clinicians | Provided insight into the contextual elements of implementation |
| Medical laboratory scientists | Laboratory processing of the procalcitonin tests |

557

558 **Table 2.** Consolidated framework for implementation research domains and constructs
 559 associated with qualitative themes

| Theme | CFIR domains | CFIR constructs |
|--|-----------------------------------|--|
| Procalcitonin intervention and implementation process | Intervention characteristics | Evidence strength and quality, Relative advantage, Adaptability, Trialability, Complexity, Design quality and packaging, Costs (opportunity) |
| | Process | Champions, Reflecting and evaluation |
| | Characteristics of the individual | Self-efficacy |
| Antimicrobial stewardship/antimicrobial resistance context | Outer setting | Patient needs and resources, Cosmopolitanism, External policy and incentives |
| | Inner setting | Culture, Tension for change, Relative priority Leadership engagement, Available resources, |
| Hospital/organisational context | Inner setting | Structural characteristics, Networks and communications, Culture, Leadership engagement |
| | Process | Champions, Available resources |