Thirty-day all-cause fatality subsequent to MRSA, MSSA and *E. coli* bacteraemia and *C. difficile* infection, 2016/17

Data to March 2017
Thirty-day all-cause fatality subsequent to MRSA, MSSA, and *E. coli* bacteraemia and *C. difficile* infection

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Thirty-day all-cause fatality subsequent to MRSA, MSSA, and *E. coli* bacteraemia and *C. difficile* infection

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Executive summary

The analysis presented here reports 30-day all-cause fatality following meticillin-resistant *Staphylococcus aureus* (MRSA), meticillin-susceptible *Staphylococcus aureus* (MSSA) and *Escherichia coli* bacteraemia (bloodstream infection) and *Clostridium difficile* infection (CDI). Thirty-day all-cause fatality is a widely-used outcome for assessing risk of death, although it should be emphasised that deaths in individual cases may or may not be attributable to these infections. Case fatality rates (CFR), a ratio of fatalities to cases, are used as they provide a standard measure, independent of the incidence of the infection, on the survivevability of an infection.

There have been large reductions in the numbers of deaths within 30-days following MRSA bacteraemia and CDI since 2007/08, reflecting decreased incidence of these infections over time. In contrast, there have been continued increases in the number of deaths within 30-days following MSSA and *E. coli* bacteraemia since surveillance was initiated in 2011/12 and 2012/13 respectively. This reflects the increased incidence of these infections. However, falling case fatality rates indicate that patients are more likely to survive these infections now, than in previous years.

In 2016/17, the CFRs following bacteraemia due to MRSA, MSSA, and *E. coli* were 28.1%, 19.7% and 14.7%, respectively. The CFR following CDI was 15.1% remaining the same as the previous financial year (15.1%). The CFRs for MRSA, MSSA and *E. coli* bacteraemia showed a small declines from the rates seen in 2015/16 (29.4%, 20.0% and 15.3%, respectively). The 30-day CFRs for all four infections have decreased since the start of their surveillance periods.

While MRSA bacteraemia consistently had the highest CFRs over time, the greatest number of deaths was seen following *E. coli* bacteraemia, due to the much higher incidence of this infection. In 2016/17 there were many more deaths following *E. coli* bacteraemia (n=5,738) than there were following MRSA bacteraemia (n=225); indeed, the number of deaths following *E. coli* bacteraemia in 2016/17 exceeded the number of deaths following MRSA bacteraemia seen in 2007/08, when the highest mortality (n=1,354) was observed for this pathogen. Although CFRs and deaths appear to be highest in the North of England, confidence intervals often overlap with those of one or more of the other regions, indicating a low level of statistical significance.
Introduction

Public Health England (PHE) has undertaken mandatory surveillance of key healthcare-associated infections (HCAIs) in England since 2001, when NHS acute trusts were mandated to report aggregate counts of bacteraemia (bloodstream infection) due to *Staphylococcus aureus*, and the number of those which were meticillin-resistant *S. aureus* (MRSA); case level MRSA reporting was introduced in 2005. Since April 2007, trusts have also been required to report all cases of *Clostridium difficile* infection (CDI) in patients aged two years or over, with the mandatory surveillance programme being expanded to include bacteraemia due to meticillin-susceptible *S. aureus* (MSSA) and *Escherichia coli* in January and June 2011, respectively. E. coli bacteraemias often occur outside of hospitals, although this does not necessarily mean these are not potentially preventable. At least one in five cases have a time of onset two or more days after admission to hospital, which is commonly taken to indicate likely acquisition of infection in hospital, and half of community-onset E. coli bacteraemias have had a healthcare-association within the past four-weeks.1-3

Large declines have been seen in the incidence of MRSA bacteraemia (81.5%) and CDI (76.8%) between the financial years (FYs) 2007/08 and 2016/17.1 In contrast, MSSA and E. coli bacteraemia have shown year-on-year increases in incidence, which although relatively small as percentage increases, translate to large increases in the number of cases due to the high incidence of both infections.1 Due to the potential impact of HCAIs on morbidity and mortality, monitoring mortality is an important part of surveillance.4 Antimicrobial resistance is also a key issue as many HCAIs are associated with high levels of resistance, which has important implications for treatment options and subsequent mortality.5 For example, MRSA infections are resistant to the recommended first-line therapy for MSSA infection (flucloxacillin), whilst around 19% of E. coli bloodstream isolates are resistant to ciprofloxacin, recommended for use in the UK only for infections caused by laboratory-confirmed susceptible strains or for the treatment of acute kidney or prostate infections.6-8 Antimicrobial resistance was recently projected to be the largest cause of death globally by 2050.9

This report presents analysis of 30-day all-cause case fatality rates (CFRs) among patients following bacteraemia due to MRSA, MSSA, or *E. coli* and CDI reported by NHS acute trusts to the national mandatory surveillance scheme; these deaths may or may not be related to the infection. Data are presented for each organism by financial year, based on the date when positive blood cultures were collected rather than when the patient died; it is therefore possible that a death occurred in a different financial year to when the positive blood culture was collected. The counts of infection reports are based on data extracted on 3 May 2017, mortality results were traced on 3 July 2017. The number of infection reports and deaths presented here may differ from those in earlier publications due to late reporting. This report uses the same base data as the 2016/17 Annual Epidemiological Commentary (AEC).1 Unlike the AEC methodology,
counts of infections and deaths have been deduplicated on a patient level to ensure that each patient can only have a single potential mortality outcome per HCAI. Presented percentage changes have been calculated using the raw figures within the supplementary tables. A full description of the methods can be found in Appendix 1.

Comparability with previous Office for National Statistics publications on mortality

The Office for National Statistics (ONS) previously published data on deaths involving MRSA and *C. difficile*. The ONS data on MRSA bacteraemia and CDI are not comparable to the data published here for a number of methodological reasons outlined in Appendix 2, Table A1. In summary, the ONS published data from England and Wales by calendar year, based on deaths which mention MRSA or *C. difficile* on the death certificate. By contrast, this publication includes data from England by financial year, with fatality calculated using all deaths occurring within 30 days of onset of MRSA bacteraemia or CDI. In addition, data are presented on fatality following MSSA and *E. coli* bacteraemia. The two outputs thus differ by geography, time period, source of death information and range of pathogens covered. We have chosen to examine all deaths (all-cause fatality) occurring within 30 days of an infection report as this is a common epidemiological convention. While it is not known if the deaths were attributable to the HCAIs, the use of all-cause fatality is no less robust than the use of data derived from death certification, which is similarly problematic due to its subjective nature.

Interpreting Case Fatality Rates

CFRs are a useful statistic to analyse the risk of death per case of a particular infection and are calculated as the number of deaths divided by the number of cases, multiplied by 100. Thus, if the ratio of deaths to cases remains constant over time so will the CFR, even if overall, there has been an increase or decrease in both the number of deaths and cases. By contrast the CFR will increase, for example, if the number of deaths increases but the number of cases remains constant, or if the number of deaths remains constant but the number of cases decreases. This means that CFR facilitates comparison between clinical outcomes of diseases with very different incidence. In addition to the CFR we have also provided 95% confidence intervals (CIs). These provide a range of values within which the true CFR is likely to lie. When confidence intervals for two or more different CFRs overlap then the true CFRs could be equal. It must be borne in mind; however, that the CFRs in this report have been derived from 30-day all-cause mortality rather than attributable mortality.
Supplementary data tables

All tables accompanying this publication are only available online and can be accessed here, and will be linked throughout the text in maroon:

MRSA bacteraemia

Table S1. Thirty-day all-cause case fatality rate following MRSA bacteraemia
Table S2. Thirty-day all-cause case fatality rate by NHS Region following MRSA bacteraemia
Table S3. Thirty-day all-cause case fatality rate by age group following MRSA bacteraemia
Table S4. Thirty-day all-cause fatality rate by gender following MRSA bacteraemia

MSSA bacteraemia

Table S5. Thirty-day all-cause case fatality rate following MSSA bacteraemia
Table S6. Thirty-day all-cause case fatality rate by NHS Region following MSSA bacteraemia
Table S7. Thirty-day all-cause case fatality rate by age group following MSSA bacteraemia
Table S8. Thirty-day all-cause case fatality rate by gender following MSSA bacteraemia

E. coli bacteraemia

Table S9. Thirty-day all-cause case fatality rate following E. coli bacteraemia
Table S10. Thirty-day all-cause case fatality rate by NHS Region following E. coli bacteraemia
Table S11. Thirty-day all-cause case fatality rate by age group following E. coli bacteraemia
Table S12. Thirty-day all-cause case fatality rate by gender following E. coli bacteraemia

C difficile infection

Table S13. Thirty-day all-cause case fatality rate following C. difficile infection
Table S14. Thirty-day all-cause case fatality rate by NHS Region following C. difficile infection
Table S15. Thirty-day all-cause case fatality rate by age group following C. difficile infection
Table S16. Thirty-day all-cause case fatality rate by gender following C. difficile infection

Overall

Table S17. Thirty-day all cause fatality rate following MRSA, MSSA, E. coli bacteraemia or C. difficile infection
**Results**

**MRSA bacteraemia**

In 2016/17, there were 823 MRSA bacteraemia cases reported to PHE, of which 800 cases (97.2%) could be linked to mortality records (Table S1); of these, 225 cases had a reported death within 30 days of the positive blood culture being taken, giving a 30-day all-cause CFR of 28.1% (95% CI: 25.0-31.4%). This represents a significant decrease (27.6%; p<0.001) when compared to the CFR of 38.9% (95% CI: 37.2-40.5%) seen in 2007/08, and a 4.3% decrease in CFR when compared to 2015/16 (29.4% (95% CI: 26.2-32.7%), however this decrease is not statistically significant (p=0.815)*. Using the CFR of 28.1% and adjusting the total number of cases to allow for a single mortality outcome per patient (n=819), the estimated total number of all-cause fatalities following MRSA bacteraemia in 2016/17 would have been 230.†

There was inter-regional variation in all-cause CFRs in 2016/17, although there was considerable overlap between NHS regions and over time in the 95% CIs (Figure 1; Table S2). The highest CFR was in the Midlands and East of England (31.0%, 95% CI: 24.7-37.9%) and the lowest in the South of England (24.6%, 95% CI: 18.7-31.3%). The reduction of 30-day all-cause CFRs also showed inter-regional variation over time, ranging from a 24.0% reduction in North of England (from 39.9%, 95% CI: 37.1-42.7% in 2007/08 to 30.4%, 95% CI: 24.8-36.4% in 2016/17) to a 32.0% reduction in London (from 36.7%, 95% CI: 32.9-40.7% in 2007/08 to 25.0%, 95% CI: 18.3-32.8% in 2016/17).

In 2016/17, the North of England and Midlands and East of England experienced the greatest number of deaths (n=78 and 62, respectively) while the South of England and London had the fewest (n=48 and 37, respectively). All NHS regions saw similar declines in the number of deaths between 2007/08 and 2016/17, ranging from an 83.5% decline in the South of England (from 291 to 48 deaths) and North of England (from 474 to 78 deaths) to an 83.1% decline the Midlands and East of England (from 366 to 62 deaths).

The highest 30-day all-cause CFRs and greatest number of deaths were observed in patients aged 85 years and over with the CFR and 95% CI overlapping with those aged 75-84 years since 2013/14, but separate for all other age groups (Figure 2; Table S3). The CFRs in patients aged 85 years and over varied over time and ranged between 58.9% (95% CI: 51.7-65.8%, n=116/197) in 2012/13, when CFR peaked, and 46.9%

*Tests for significant reductions (p-value) of 30-day mortality calculated over financial years assessed using generalised linear models with pairwise comparisons.
†For full methods, equations and calculations, see Appendix 1: Methods.
Thirty-day all-cause fatality subsequent to MRSA, MSSA, and *E. coli* bacteraemia and *C. difficile* infection

(95% CI: 39.0-54.9%, n=76/162) in 2016/17. The <1 and 1-14 year age groups had low numbers of deaths since the start of enhanced MRSA surveillance with a cumulative count of 20 and 8 deaths, respectively, between 2007/08 and 2016/17.

**Figure 1. Thirty-day all-cause case fatality rate by NHS Region following MRSA bacteraemia**

Numerically, more deaths and infections were observed among males. In 2016/17 there were 142 deaths among males and 83 among females; however, the 30-day all-cause CFRs among males and females were comparable across all time periods (Figure 3; Table S4). The CFRs among both genders decreased overall since 2007/08, with an overall 30.0% reduction in CFR in males from 38.6% (95% CI: 36.5-40.6%) in 2007/08 to 27.0% (95% CI: 23.2-31.0%) in 2016/17 and a 23.2% reduction in CFR in females from 39.6% (95% CI: 36.8-42.4%) in 2007/08 to 30.4% (95% CI: 25.0-36.2%) in 2016/17. An overall increase in CFR has been observed since 2014/15 for females; however, there is little evidence that this change is not due to chance variation. Cases where the gender was reported as 'unknown' have been excluded from Figure 3. This data is; however, retained in the accompanying supplementary table (Table S4).
Thirty-day all-cause fatality subsequent to MRSA, MSSA, and *E. coli* bacteraemia and *C. difficile* infection

**Figure 2.** Thirty-day all-cause case fatality rate by age group following MRSA bacteraemia

**Figure 3.** Thirty-day all-cause fatality rate by gender following MRSA bacteraemia
MSSA bacteraemia

In 2016/17, there were 11,486 MSSA bacteraemia cases reported to PHE, of which 11,110 (96.7%) could be linked to mortality records (Table S5); of these, 2,192 cases had a death reported within 30 days, giving a 30-day all-cause CFR of 19.7% (95% CI: 19.0-20.5%). Between 2011/12 and 2016/17 the CFR declined by 8.1% (p<0.001)*, from 21.5% (95% CI: 20.6-22.4%, n=1,777/8,279) to 19.7% (95% CI: 19.0-20.5%), and a 1.5% decrease in CFR when compared to 2015/16 (20.0% (95% CI: 19.3-20.8%), however this decrease is not stastically significant (p=0.593)*. Using the CFR of 19.7% and adjusting the total number of cases to allow for a single mortality outcome per patient (n=11,475), the estimated total number of all-cause fatalities in 2016/17 was 2,264.‡

In 2016/17, the highest number of deaths was in the North of England (n=711), with the lowest in London (n=258) (Figure 4; Table S6). All NHS regions saw an increase in deaths between 2011/12 and 2016/17, ranging from 13.6% (626 to 711 deaths) in the North of England, to 37.7% (422 to 581 deaths) in the South of England. However, a decline in the 30-day all-cause CFRs has been observed in all NHS regions since 2011/12. In 2016/17 the CFR ranged from 17.3% (95% CI: 15.4-19.3%) in London to 20.8% (95% CI: 19.3-22.2%) in the Midlands and East of England. Although there was some variation between regions, there was overlap between the confidence intervals for all regions over time and between each region (Figure 4).

The 30-day all-cause CFRs and number of deaths varied by age group (Figure 5; Table S7). In 2016/17 the lowest CFR was seen in 1-14 year olds (1.6%, 95% CI: 0.7-3.1%, n=8) with the highest in those aged 85 years and over (45.5%, 95% CI: 42.9-48.0%, n=689). In all time periods observed, 1-14 year olds had the lowest CFRs and number of deaths and the CFRs were higher in the <1 year age group compared to both 1-14 and 15-44 year olds (Figure 5). In 2016/17 the respective CFRs of 1-14 and 15-44 year olds were: 1.6% (95% CI: 0.7-3.1%) and 4.5% (95% CI: 3.6-5.5%), while the CFR of <1 year age group was 4.9% (95% CI: 3.0-7.5%, n=19).

A greater number of deaths were observed among males than females; however, the CFR was higher among females (Figure 6; Table S8). For example in 2016/17 there were 1,326 deaths among men and 866 among women while the equivalent CFRs were 18.7% (95% CI: 17.8-19.6%, n=1,326/7,106) and 21.7% (95% CI: 20.4-23.0%, n=866/3,990). Cases where the gender was reported as ‘unknown’ have been excluded from Figure 6. This data is; however, retained in the accompanying table (Table S8).

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* Tests for significant reductions (p-value) of 30-day mortality calculated over financial years assessed using generalised linear models with pairwise comparisons.
‡ For full methods, equations and calculations, see Appendix 1: Methods.
Thirty-day all-cause fatality subsequent to MRSA, MSSA, and *E. coli* bacteraemia and *C. difficile* infection

Figure 4. Thirty-day all-cause case fatality rate by NHS Region following MSSA bacteraemia

![Graph showing fatality rate by NHS Region](image)

- London
- Midlands and East of England
- North of England
- South of England

Figure 5. Thirty-day all-cause case fatality rate by age group following MSSA bacteraemia

![Graph showing fatality rate by age group](image)

- <1 yr
- 1-14 yrs
- 15-44 yrs
- 45-64 yrs
- 65-74 yrs
- 75-84 yrs
- ≥ 85 yrs
Figure 6. Thirty-day all-cause case fatality rate by gender following MSSA bacteraemia

**Escherichia coli bacteraemia**

There were 40,580 *E. coli* bacteraemia cases reported to PHE in 2016/17, of which 39,145 (96.5%) could be linked to mortality records (Table S9); of these, 5,738 cases died within 30 days of the positive blood culture being taken, giving a 30-day all-cause CFR of 14.7% (95% CI: 14.3-15.0%). Between 2012/13 and 2016/17 the CFR declined by 13.0% (p<0.001) from 16.8% (95% CI: 16.4-17.3%, n=5,163/30,659) to 14.7% (95% CI: 14.3-15.0%), and a 4.1% decrease (p=0.004) in CFR when compared to 2015/16 (15.3% (95% CI: 14.9-15.7)). Using the CFR of 14.7% and adjusting the total number of cases to allow for a single mortality outcome per patient (n=40,513), the estimated total number of all-cause fatalities in 2016/17 was 5,939. 

All NHS regions observed an increase in the number of deaths between 2012/13 and 2016/17 (Figure 7; Table S10). In 2016/17, the NHS region with the greatest number of deaths was the North of England (n=1,978); this represented an increase of 5.6% compared to the number seen in 2012/13 (n=1,873), and was the smallest observed

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1 Tests for significant reductions (p-value) of 30-day mortality calculated over financial years assessed using generalised linear models with pairwise comparisons.

2 For full methods, equations and calculations, see Appendix 1: Methods.
increase among all regions. The South of England saw the largest increase (20.7%) from 1,131 to 1,365.

All regions saw a reduction in CFRs compared to those seen in 2012/13. In 2016/17 the 30-day all-cause CFRs ranged from 12.7% (95% CI: 11.8-13.6%) in London to 15.6% (95% CI: 14.9-16.2%) in the North of England (Figure 7).

**Figure 7. Thirty-day all-cause case fatality rate by NHS Region following *E. coli* bacteraemia**

There was variation in the 30-day all-cause CFRs and the number of deaths by age group (Figure 8; Table S11). In all financial years the lowest CFRs and fewest deaths were in 1-14 year olds (4.0%, 95% CI: 1.8-7.5%, n=9 in 2016/17). In 2016/17, the number of deaths and CFR in the <1 year old age group (10.7%, 95% CI: 8.4-13.4%, n=66) were higher than those in 1-14 year olds and the CFR was higher than those aged 15-44 years old. The highest CFR and number of deaths in all financial years were in those aged 85 years or more (21.8%, 95% CI: 20.9-22.6%, n=1,977 in 2016/17). All age groups experienced an overall decrease in CFR between 2012/13 and 2016/17. The largest CFR decrease of 19.7% was observed in the 65–74 year age group from 15.6% (95% CI: 14.7-16.5%) in 2012/13 to 12.5% (95% CI: 11.8-13.3%).
Thirty-day all-cause fatality subsequent to MRSA, MSSA, and *E. coli* bacteraemia and *C. difficile* infection

**Figure 8. Thirty-day all-cause case fatality rate by age group following *E. coli* bacteraemia**

There were increases in the number of deaths among both males and females between 2012/13 and 2016/17 (from 2,723 to 3,108 and from 2,316 to 2,617, respectively) (Table S12). However, due to a greater increase in the number of infections relative to the number of deaths for both genders, the CFR declined slightly over the same time period (Figure 9). In 2016/17 the CFR among men was higher than that among women; 16.5% (95% CI: 16.0-17.1%) versus 12.9% (95% CI: 12.5-13.4%), respectively; an observation made in all years. Cases where the gender was reported as ‘unknown’ have been excluded from Figure 9. This data is, however, retained in the accompanying table (Table S12).
Thirty-day all-cause fatality subsequent to MRSA, MSSA, and *E. coli* bacteraemia and *C. difficile* infection

**Figure 9. Thirty-day all-cause case fatality rate by gender following *E. coli* bacteraemia**

![Graph showing 30-day all-cause fatality rate by gender following *E. coli* bacteraemia](image)

*Clostridium difficile* infection

In 2016/17, 12,840 cases of CDI were reported to PHE (Table S13), of which 12,504 (97.4%) could be linked to mortality records; of these cases, 1,887 had a reported death within 30 days of the positive faecal specimen being taken, giving a 30-day all-cause CFR of 15.1% (95% CI: 14.5-15.7%). Between 2007/08 and 2016/17 the CFR declined by 42.5% (p<0.001) from 26.2% (95% CI: 25.9-26.6%, n=13,940 /53,145) to 15.1% (95% CI: 14.5-15.7%). There was no change in CFR between 2015/16 to 2016/17; however, there were fewer reported cases and 30-day all-cause fatalities in 2016/17. Using the CFR of 15.1% and adjusting the total number of cases to allow for a single mortality outcome per patient (n=12,835), the estimated total number of all-cause fatalities in 2016/17 was 1,937.**

Geographically there was wide variation in the number of deaths observed in 2016/17. The greatest number of deaths were seen in the North of England NHS region (n=641), the number being nearly three times greater than that seen in London (n=220), the NHS region with the lowest number of deaths (Table S14). All NHS regions saw similar trends, with a national decline of 86.5% (regional range 85.8-86.8%) in the number of deaths between 2007/08 and 2016/17. In 2016/17 the CFRs ranged from 13.9% (95% CI: 13.5-14.3%) to 15.1% (95% CI: 14.5-15.7%).

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* Tests for significant reductions (p-value) of 30-day mortality calculated over financial years assessed using generalised linear models with pairwise comparisons.
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Thirty-day all-cause fatality subsequent to MRSA, MSSA, and *E. coli* bacteraemia and *C. difficile* infection

CI: 12.2-15.7% in London to 15.5% (95% CI: 14.3-16.7%) in the Midlands and East of England (Figure 10), but with overlaps between regions in the confidence intervals around the CFR.

**Figure 10. Thirty-day all-cause case fatality rate by NHS Region following *C. difficile* infection**

The 30-day all-cause CFRs and number of deaths increased with age (Figure 11; Table S15). In 2016/17 there were no deaths among 2-14 year olds, while among those aged 85 years and over there were 775 deaths; a CFR of 24.0% (95% CI: 22.5-25.5%, n=775/3,231). The CFR in patients aged 85 years and over remained significantly higher than that in all other age groups over time. However, all age groups have seen a decline in the number of deaths and the CFRs from 2007/08 to 2016/17.

There were consistently more deaths among females compared to males over time; for example in 2016/17 there were 1,037 and 848 deaths, respectively (Table S16). However, due to differences in the number of infection reports during 2016/17, the CFR remained higher among males (16.3%, 95% CI: 15.3-17.3%, n=848/5,215) compared to females (14.3%, 95% CI: 13.5-15.1%; n=1,037/7,269) (Figure 12). Both females and males experienced a decline in CFR between 2007/08 and 2016/17, declining by 44.3% from 25.6% (95% CI: 25.1-26.1%; n=7,822/30,550) to 14.3% (95% CI: 13.5-15.1%; n=1,037/7,269) in females and by 39.9% from 27.1% (95% CI: 26.5-27.7%; n=5,942/21,959) to 16.3% (95% CI: 15.3-17.3%; n=848/5,215) in males. Cases where the gender was reported as 'unknown' have been excluded from Figure 12. This data is; however, retained in the accompanying table (Table S16).
Thirty-day all-cause fatality subsequent to MRSA, MSSA, and *E. coli* bacteraemia and *C. difficile* infection

Figure 11. Thirty-day all-cause case fatality rate by age group following *C. difficile* infection

![Figure 11](image1)

Figure 12. Thirty-day all-cause case fatality rate by gender following *C. difficile* infection

![Figure 12](image2)
Discussion

There was a significant decrease in the 30-day all-cause CFRs for all four infections over the study period. The small changes in the patient age distributions over time did not significantly affect CFR trends. The decline in the CFRs for MRSA bacteraemia and CDI, coupled with reductions in infection rates was reflected in rapid declines in the number of deaths following these infections since 2007/08 (Figure 13; Table S17). The declines in the CFRs show how for MRSA bacteraemia and CDI, the number of deaths decreased more rapidly than the number of infections while for MSSA and E. coli bacteraemia the increase in deaths was slower than the increase in the numbers of infections. The largest reduction (42.5%) in 30-day all-cause CFR was seen in CDI. This may be associated with declines in infections caused by C. difficile ribotype 027, which historically predominated in England and has been associated with higher mortality compared to other strains.\textsuperscript{13} Additionally, there has been a shift in CDI epidemiology in England in which the time of onset went from being mostly hospital-onset in 2007/08 to mostly non-hospital-onset from 2011/12 onwards.\textsuperscript{1} Nonetheless mortality among CDI patients remains a concern; an English study published in 2013 found around 15% of patients with CDI died in hospital compared to around 2% of patients without CDI. Notably, in the aforementioned study, where the ribotype was known (72% of cases), none of the patients within the study had infection caused by 027.\textsuperscript{14}

With regard to the increase in the MRSA bacteraemia CFR in 2012/13 (Figure 14; Table S17), this may be related to an excess in all-cause fatality associated with respiratory causes noted during the winter of 2012/13.\textsuperscript{15} This is; however, set against the general downward trend observed in CFR. Furthermore the confidence intervals for the CFR in 2012/13 overlap with those of the surrounding years; thus, the CFR is not significantly different from other years.

The declines observed over time in the CFRs following MSSA and E. coli bacteraemia are relatively small in proportion compared to those for MRSA bacteraemia and CDI. Notably, while the CFR following E. coli bacteraemia was lower than those for MRSA and MSSA bacteraemias, the relatively high incidence of this blood stream infection equates to a greater number of deaths. As an indication of the public health burden of mortality following E. coli bacteraemia, the number of deaths observed in a single year for E. coli bacteraemia in 2016/17 (n=5,738) was higher than the cumulative number of 30-day all-cause fatalities following MRSA bacteraemia since 2007/08 (n=5,042).

The decline over time in the CFR for CDI has continued a downward trend, and has a similar CFR to that for E. coli bacteraemia as shown by overlap between the confidence intervals of CDI and E. coli since 2014/15 (Figure 14; Table S17).
Thirty-day all-cause fatality subsequent to MRSA, MSSA, and *E. coli* bacteraemia and *C. difficile* infection

**Figure 13. Number of deaths within 30-days of specimen collection by infection**

![Graph showing number of deaths by infection over years](image)

**Figure 14. Thirty-day all-cause case fatality rate by infection**

![Graph showing fatality rate by infection over years](image)
The most striking patterns in the 30-day all-cause CFRs were by age, with a general increase in CFR by age. For all four infections, patients aged 85 years and over had a significantly higher CFR compared to other age groups (except MRSA bacteraemia in 2012/13 onwards, where there is overlap with those aged 75-84 years, notably in 2016/17). Among patients aged 0-1 year with MSSA and *E. coli* bacteraemia, the CFR was higher than that for 1-14 and 15-44 year olds, which is similar to the pattern observed for the incidence of these bacteraemias. A single death was reported in the 0-1 year age group for MRSA bacteraemia reported in 2016/17; however, no deaths were reported between 2011/12 and 2015/16. It is not possible to assess mortality rates in patients less than two years old with CDI as infections in this age group are not reported to PHE (see Appendix 1).

Case fatality was consistently and significantly higher among males than females following CDI and *E. coli* bacteraemia. Among MSSA bacteraemia cases the CFR was consistently higher among females. MRSA bacteraemia had CFRs that were broadly similar by gender in the past five years, although in 2015/16, females exhibited a higher CFR than males; however, the confidence intervals overlapped suggesting this may not be a true deviation from the trend.

There were some large differences in the number of deaths and CFRs by region, for example for *E. coli* bacteraemia in London and the North of England. However, in many instances the overlap in the confidence intervals associated with the CFRs indicated that these inter-regional differences in outcome were unlikely to be statistically significant. Use of generalised linear models adjusted for age, sex and region demonstrated that for all four infections, no single NHS region was significantly different from each of the other three.

**Limitations**

The ONS has historically published statistics on deaths involving MRSA and *C. difficile*; these statistics are incomparable with those presented here for the reasons highlighted in the Introduction.

The analyses presented here are based on infections reported to PHE that could be linked to the NHS Spine to obtain mortality information. While the majority of infection reports had complete NHS numbers (required for linkage), for occasional reports the NHS Spine was not able to return patient information, for reasons such as the NHS number and date of birth not matching a record on the NHS Spine. Thus, there may be bias in the records with available mortality information, which may over- or under-estimate the number of deaths and associated CFRs, if the records without mortality information were for patients more or less likely to have died. Additionally crude CFRs are presented and as such have not been adjusted for potential confounders such as age, gender or co-morbidities, which may affect comparisons over time and between regions. However the use of generalised linear models to provide estimates of the
adjusted odds ratios of CFR for each infection by controlling for age and gender, found that the crude CFR and adjusted CFR were similar, implying that the crude CFRs provide an appropriate estimate. Pairwise estimates following regression were used to test if changes in CFR were significant. Finally, while analysis of 30-day all-cause fatality enumerates the risk of death following an infection within a fixed time frame it does not provide insight into attributable mortality. However, it is difficult to ascertain attributable mortality in practice, due to clinical and diagnostic uncertainty encountered when trying to determine the exact cause of death in patients, particularly in those with multiple co-morbidities.
Appendix 1: Methods

Data on MRSA, MSSA, and \textit{E. coli} bacteraemia and CDI were extracted on 03 May 2017 from the HCAI Data Capture System (DCS). Reports of CDI made in patients aged under 2 years at the time of specimen collection were excluded from all analyses because this data is not mandatorily collected as carriage rates are high\textsuperscript{17} with little evidence for disease.\textsuperscript{18} Mortality estimates cover the period 2007/08 to 2016/17 for MRSA bacteraemia and CDI; 2011/12 to 2016/17 for MSSA bacteraemia; and, 2012/13 to 2016/17 for \textit{E. coli} bacteraemia.

Mortality information was obtained by batch tracing the extracted MRSA, MSSA, and \textit{E. coli} bacteraemia and CDI data against the NHS Spine, a central repository of patient demographic and medical information managed by the Health and Social Care Information Centre. Records were traced using the NHS number and date of birth (DoB). Only records that match on both the NHS number and the DoB can be successfully traced and have the potential for mortality information to be returned. Within the HCAI DCS, NHS number and DoB are mandatory fields for entering and saving a case onto the surveillance system; users can enter "9"s in place of a valid NHS number if the NHS number is unknown, while 01/01/1900 is used for DoB if it is unknown. Only traced reports are considered when calculating CFR (see footnote i).

Records between 2007/08 and 2014/15 were originally traced on 04 July 2015; a secondary trace was conducted on all records from financial years' 2013/14 to 2016/17 on 03 July 2017. A retrace of the previous two financial years was undertaken to capture updated reports, including the addition of new reports or updates of existing reports, entered into NHS Spine during the current financial year, resulting in minor changes to previous years' final counts (see footnote ii).

For infection reports with a death reported in the NHS Spine, the time in days between specimen date and date of death was calculated to identify whether it was within the 30-day window included in the case fatality calculations. Reports where the date of death was 2 or more days before the specimen date for bacteraemias, or 3 or more days before the specimen date for CDI were excluded from the analysis. On the HCAI DCS, MRSA, MSSA and \textit{E. coli} bacteraemia episodes are 14-days, and CDI episodes are 28-days, therefore it is possible to have multiple episodes within 30-days of a death. Where multiple records had the same NHS number and date of birth (within each bacteraemia

\textsuperscript{i} Some records had valid a NHS numbers and date of birth but failed to trace to the NHS Spine; this involved the following number of records across all reported financial years (and percentage of total records) for each infection: MRSA bacteraemia, 649 (4%); MSSA bacteraemia, 1474 (2.5%); \textit{E. coli} bacteraemia, 4776 (2.6%); CDI 6170 (2.7%).

\textsuperscript{ii} This involved the following number of new/updated reports (and count of updated reports with a death within the 30-day mortality window) for each infection in previous years' data: MRSA bacteraemia, 4 (0); MSSA bacteraemia, 51 (7); \textit{E. coli} bacteraemia, 188 (9); CDI 15 (3).
or CDI) within the 30-day mortality window, only the final specimen date was used to calculate 30-day all-cause CFR. Bacteraemia or CDI reports where the date of death was one day or two days, respectively, before the specimen date, were included in the 30-day fatality group (see footnote iii); however, these records were only retained in the mortality calculations if the patient did not have a sample taken 30-days prior to their date of death. These data were deduplicated for when a patient (by NHS number and DoB) had more than one record flagged for death (within the 30-day window), per organism. Where this occurs, only the record with specimen date closest to the date of death is associated with 30-day all-cause mortality. This was done to prevent estimate bias by overestimating the numbers of deaths. This deduplication algorithm was applied to both the 30-day mortality, traced and total number of reports to prevent an inflated count of deaths and reports (see footnote iv).

CFR was calculated by financial year (of the bacteraemia or CDI), region, age and gender; these were calculated for each organism as follows:

$$30\text{-day all-cause CFR} = \left(\frac{\sum 30\text{-day mortality traced reports}}{\sum \text{traced reports}}\right) \times 100$$

The total number of reports were deduplicated in two stages on a bacteraemia or CDI level: first by traced records to where individuals had multiple specimen dates within the 30-day mortality window, only the final specimen date, and dates outside the 30-day window were retained; and second, where records which had a valid NHS number and date of birth, but did not successfully trace, deduplicating any records which occurred within 30-days of the final specimen date, retaining the final specimen date and those outside the 30-day window.

A crude estimate of the total number of deaths within 30 days of the infection report was calculated for each organism by multiplying the total number of deduplicated infection reports submitted to the HCAI DCS for a given financial year by the 30-day CFR (expressed as a proportion) rounded to the nearest whole number.

The estimated total number of 30-day all-cause deaths was calculated as follows:

$$\text{Estimated total number 30-day all-cause deaths} = (\text{Deduplicated total reports}) \times (30\text{-day all-cause CFR})$$

---

iii This involved the following number of reports (and percentage of deaths reported) for each infection: MRSA bacteraemia, 11 (0.22%); MSSA bacteraemia, 24 (0.21%); E. coli bacteraemia, 61 (0.22%); CDI, 174 (0.38%).

iv This involved the following number of deduplicated mortality reports (and percentage of deaths reported) for each infection: MRSA bacteraemia, 50 (0.98%); MSSA bacteraemia, 115 (1.00%); E. coli bacteraemia, 407 (1.47%); CDI, 331 (0.72%).
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This provides an estimate of the number of deaths that might be observed in a given time period if all infection reports could have been linked to mortality records, assuming the risk of death was the same for those records that could and could not be linked.

Percentage changes were calculated for reported deaths and CFRs by financial year (of the bacteraemia or CDI), region, age and gender; these were calculated for each organism as follows:

\[ v_c = \text{value (deaths or CFR) from the current financial year (2016/17), and;} \]
\[ v_f = \text{value (deaths or CFR) from the first financial year of surveillance}\]

\[
\text{Percentage change} = \left( \frac{v_c - v_f}{v_f} \right) \times 100
\]

The CFR includes 95\% confidence intervals calculated using a binomial distribution. Z-tests comparing two proportions were used to determine significant differences in the 30-day all-cause CFR over time, controlling for age, gender and region, assessed using multivariate regression.

Sample calculations for CFR (not including 95\% CI), estimated total number of 30-day all-cause deaths, and percentage change for MRSA in 2016/17. Note that all calculations within the report use the raw figures found in the supplementary tables, figures in the report will be rounded to one decimal place for simplicity:

\[
\text{30-day all-cause CFR}_{\text{MRSA 2016/17}} = \left( \frac{225 \text{ deaths}}{800 \text{ deduplicated traced reports}} \right) \times 100 = 28.1\%
\]

\[
\text{Est. total number 30-day all-cause deaths}_{\text{MRSA 2016/17}} = \left( 819 \text{ mortality deduplicated DCS reports} \right) \times (0.281) = 230
\]

\[
\text{CFR percentage change}_{\text{MRSA 2007/08 to 2016/17}} = \left( \frac{28.125 - 38.863}{38.9} \right) \times 100 = -27.6\%
\]

\[
\text{Deaths percentage change}_{\text{MRSA 2007/08 to 2016/17}} = \left( \frac{225 - 1,354}{1,354} \right) \times 100 = -83.4\%
\]
Appendix 2: Summary of differences between Office for National Statistics and PHE mortality outputs

Table A1: Summary of differences in methodology between the ONS and PHE mortality publications

<table>
<thead>
<tr>
<th></th>
<th>ONS</th>
<th>PHE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geography</td>
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<td>England</td>
</tr>
<tr>
<td>Time period covered</td>
<td>Calendar year</td>
<td>Financial year</td>
</tr>
<tr>
<td>Mortality data source</td>
<td>Death registrations</td>
<td>NHS Spine reports of death</td>
</tr>
<tr>
<td>Deaths relating to</td>
<td>MRSA bacteraemia and <em>C. difficile</em></td>
<td>MRSA, MSSA, <em>E. coli</em> bacteraemia and <em>C. difficile</em> infection</td>
</tr>
<tr>
<td>Deaths determined by</td>
<td>Mention of MRSA or <em>Clostridium difficile</em> on the death certificate (where the patient need not have died from MRSA or <em>C. difficile</em>) and where MRSA or <em>C. difficile</em> were the underlying cause of death.</td>
<td>Deaths within 30 days of positive specimen of MRSA, MSSA or <em>E. coli</em> bacteraemia or <em>C. difficile</em> infection determined using data matched with the NHS Spine.</td>
</tr>
<tr>
<td>Denominator</td>
<td>All deaths in the given time period and population in the given time period (two different denominators used)</td>
<td>All traced reports of MRSA, MSSA, <em>E. coli</em> bacteraemia or CDI in the given time period</td>
</tr>
</tbody>
</table>
Thirty-day all-cause fatality subsequent to MRSA, MSSA, and *E. coli* bacteraemia and *C. difficile* infection

References


