

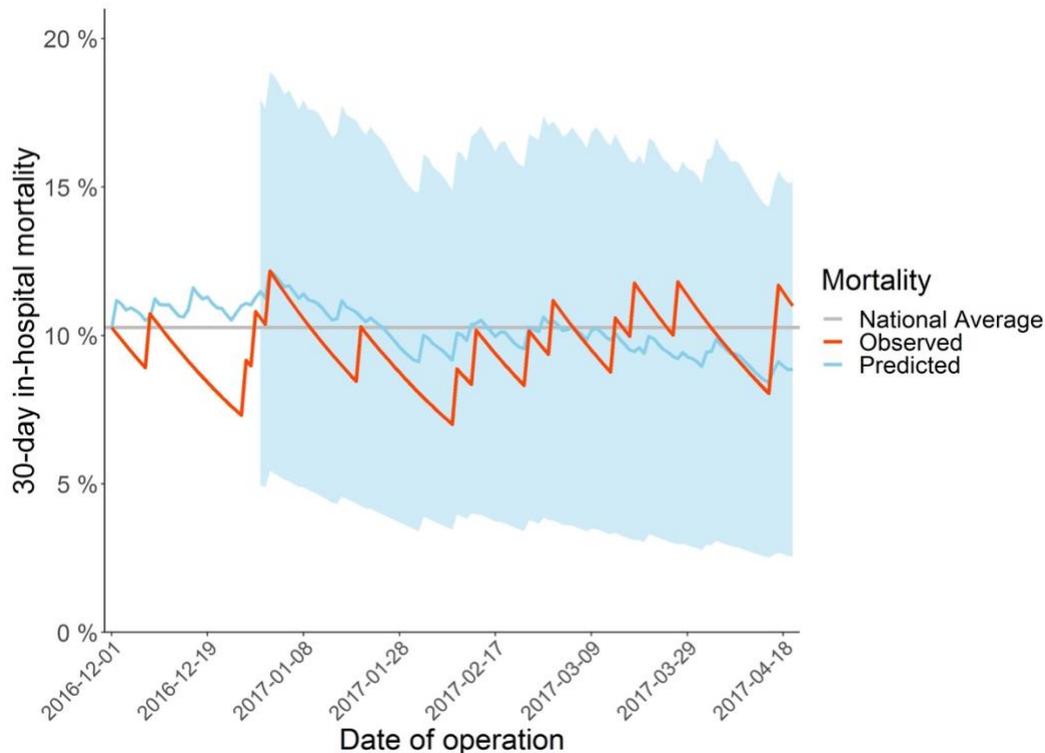
What is a EWMA chart and how do I read it?

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What is a EWMA chart?

A EWMA chart is a method for monitoring the outcomes of patients within a single hospital in real time. It can be used to evaluate whether the patient outcomes in a hospital are within the range of expected outcomes, given the hospital's casemix of patients. EWMA charts can be used as a warning system for early detection of problematic performance. If the chart indicates that outcomes might be worse than expected, hospital staff should work together to investigate possible causes. The EWMA charts shown in this document are based on the publication by Cook et al (2011).

Here is an example of a EWMA chart.¹



The EWMA chart compares three things:

- the **national average mortality rate** in the previous year² (**grey line**),
- the **observed mortality rate** in your hospital (**red line**), and
- the **predicted mortality rate** given your hospital's casemix³ (**blue line**).

¹ All charts in this document are based on simulated data.

² We use the previous year's national average as the best available estimate of the current national average.

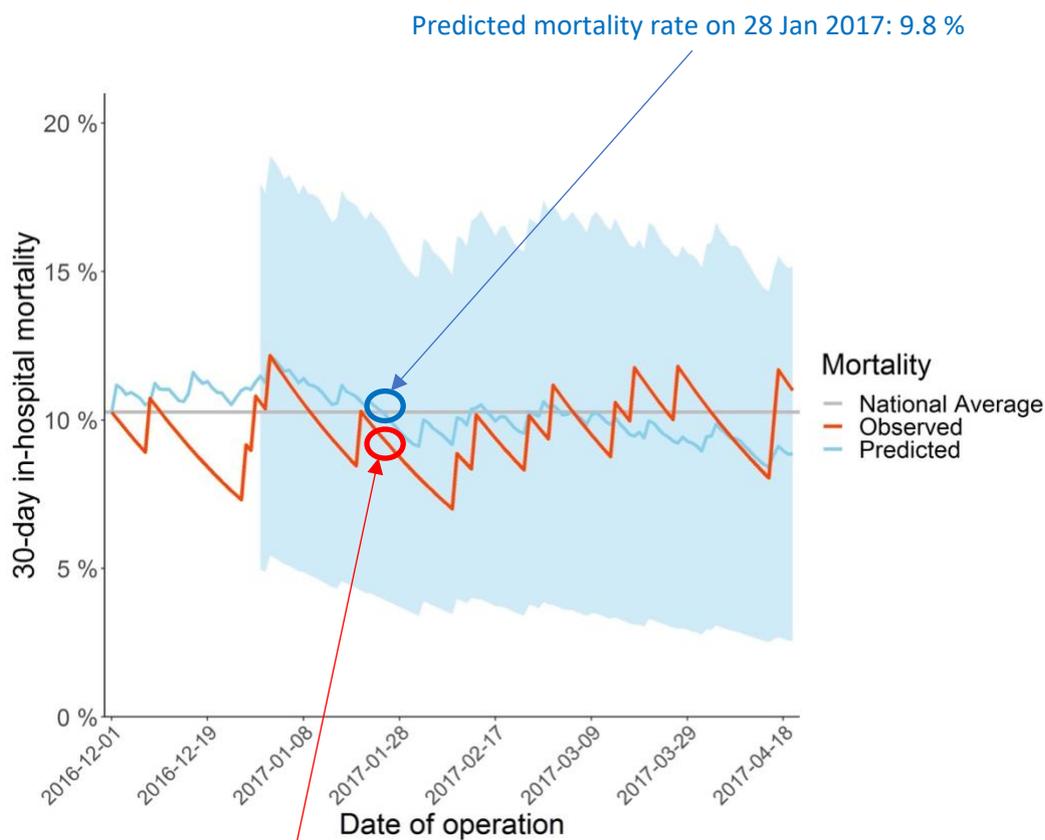
³ The predicted mortality rate is calculated from the information your hospital provides about the patients undergoing emergency laparotomy, using the NELA risk prediction model.

The EWMA chart also gives a margin of error around the predicted mortality rate. This is shown as a blue cloud. The edges of the cloud are called **control limits**. We will say more about control limits soon.

A EWMA chart monitors mortality over time. As patients are discharged and their records are locked on your NELA database, they will be included in the chart, and the chart will be extended. For example, the chart above shows all patients whose emergency laparotomies were conducted between December 2016 and April 2017. As time moves on, the chart will be extended to the right.

Why is it called “EWMA”?

EWMA stands for “**exponentially weighted moving average**”. The name refers to the way the observed and predicted mortality rates are calculated. At any given point in time, the mortality rate displayed is the average of all patients that were treated between the start of the chart and that point in time. However, in the calculation of this average, more recent patients are given stronger weight than patients whose operations were a long time ago. At any point in time, the position of the curve gives an estimate of the ‘current’ mortality rate (observed or predicted).



How do I interpret a EWMA chart?

The EWMA chart gives information about your hospital's current mortality rate, about your hospital's casemix, and the national average mortality. Comparing these figures can give you important information about your hospital's patients and their outcomes.

Comparing your hospital's predicted and observed mortality rates:

If the **observed mortality rate** is lower than the **predicted mortality rate**, this means that fewer patients died than predicted by the NELA risk model. If the **observed mortality rate** is higher than **predicted**, this means that more patients died than predicted by the NELA risk model.

Comparing your hospital's predicted and the national average mortality rates:

If your hospital's **predicted mortality rate** is below the **national average**, this indicates that your hospital's patients have a below-average risk of 30-day mortality, i.e. you have recently been seeing patients who are relatively lower risk than the national average. If the **predicted mortality rate** is above the **national average**, this means that your hospital's recent casemix has relatively higher risk than the national average.

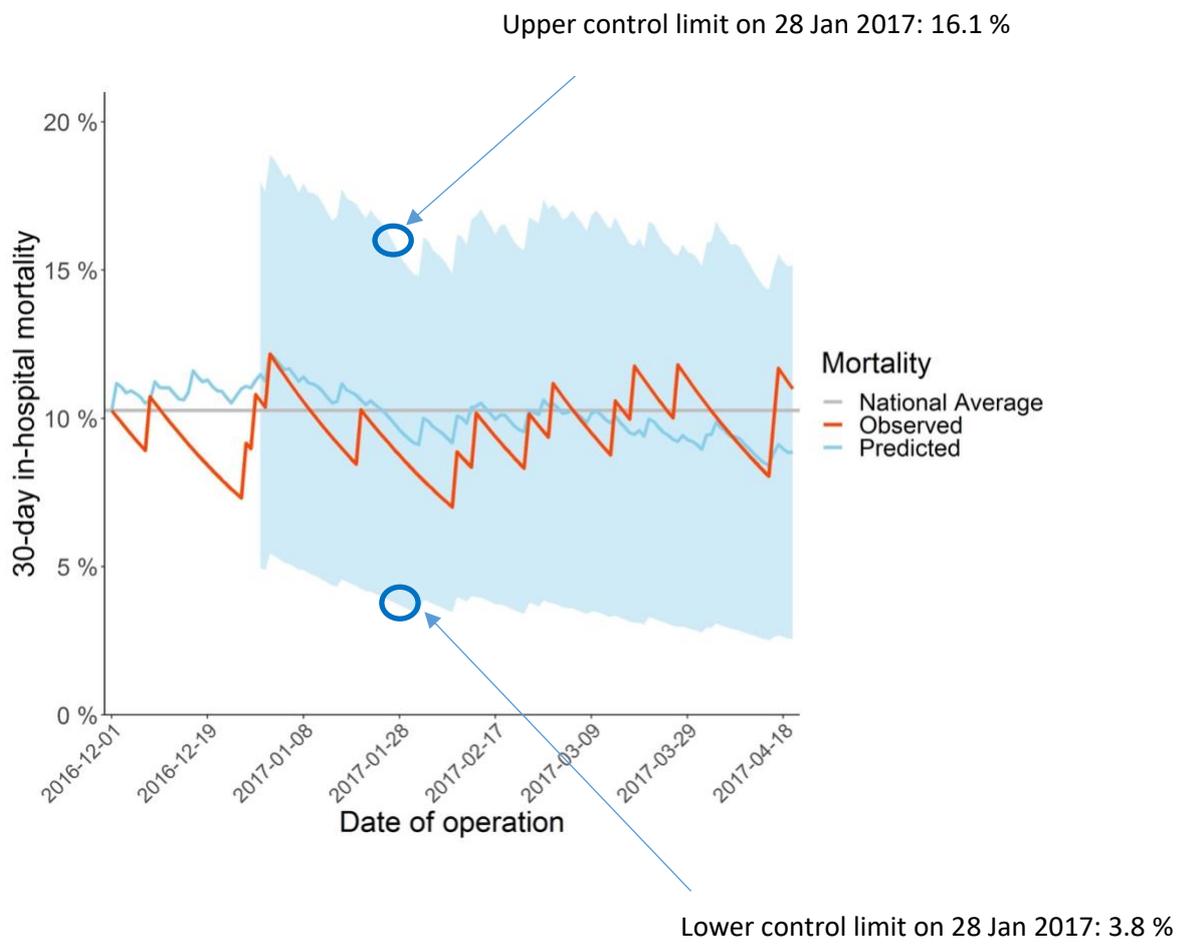
Small differences are probably not meaningful.

The predicted and observed mortality rates vary randomly to some extent. Small fluctuations of either rate probably do not mean that your casemix or your mortality rate has changed in an important way. Similarly, you may see small differences between the observed and predicted mortality rates, or between each of those and the national average. Such small differences probably do not mean that your hospital is performing better or worse than predicted, or that it has an unusual casemix.

But large differences need to be investigated.

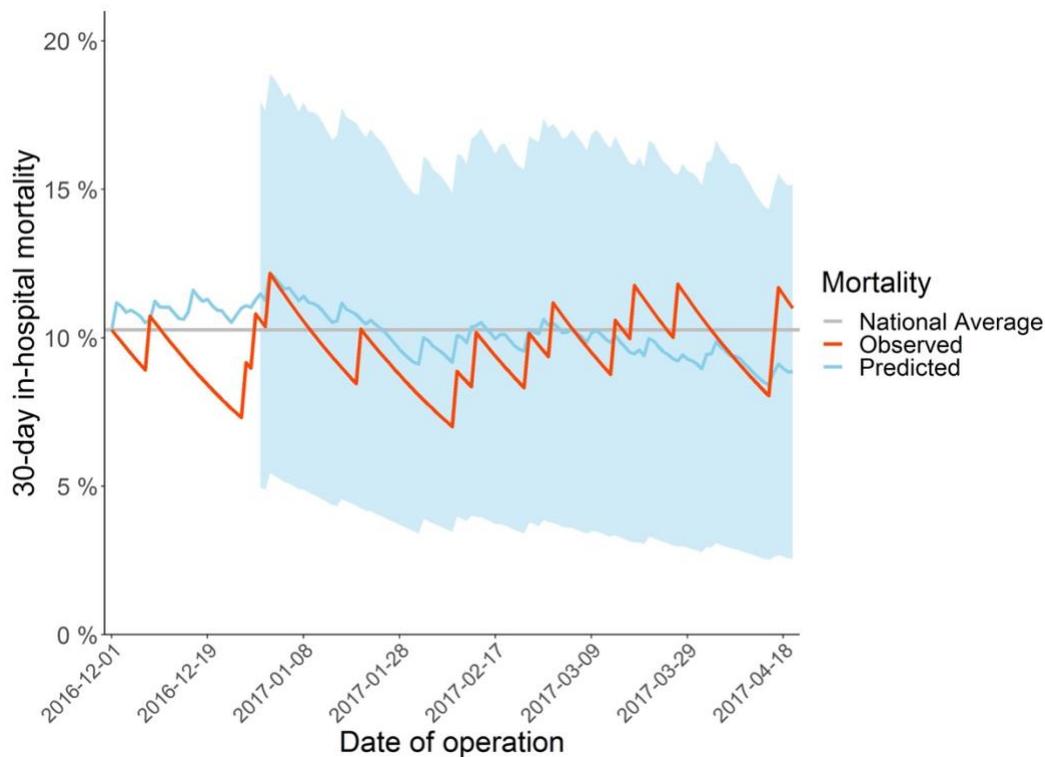
A large difference between observed and predicted mortality should be investigated. How large does a difference need to be to warrant investigation? As guidance, we have provided statistical control limits – shown in the EWMA chart as a blue “cloud”. We don't show control limits for the first 30 patients, because with few data to go on, control limits for this type of chart are not statistically reliable.

The example chart below illustrates the control limits. If the **observed mortality** moves above the upper control limit (above the cloud), you should investigate potential causes why mortality in your hospital might be higher than predicted by the NELA risk model. Similarly, if the observed mortality moves below the lower control limit (below the cloud), you may wish to investigate potential reasons why mortality in your hospital may be lower than predicted. We will now look at two hypothetical example to illustrate the interpretation of EWMA charts and control limits.



Example 1: No cause for concern

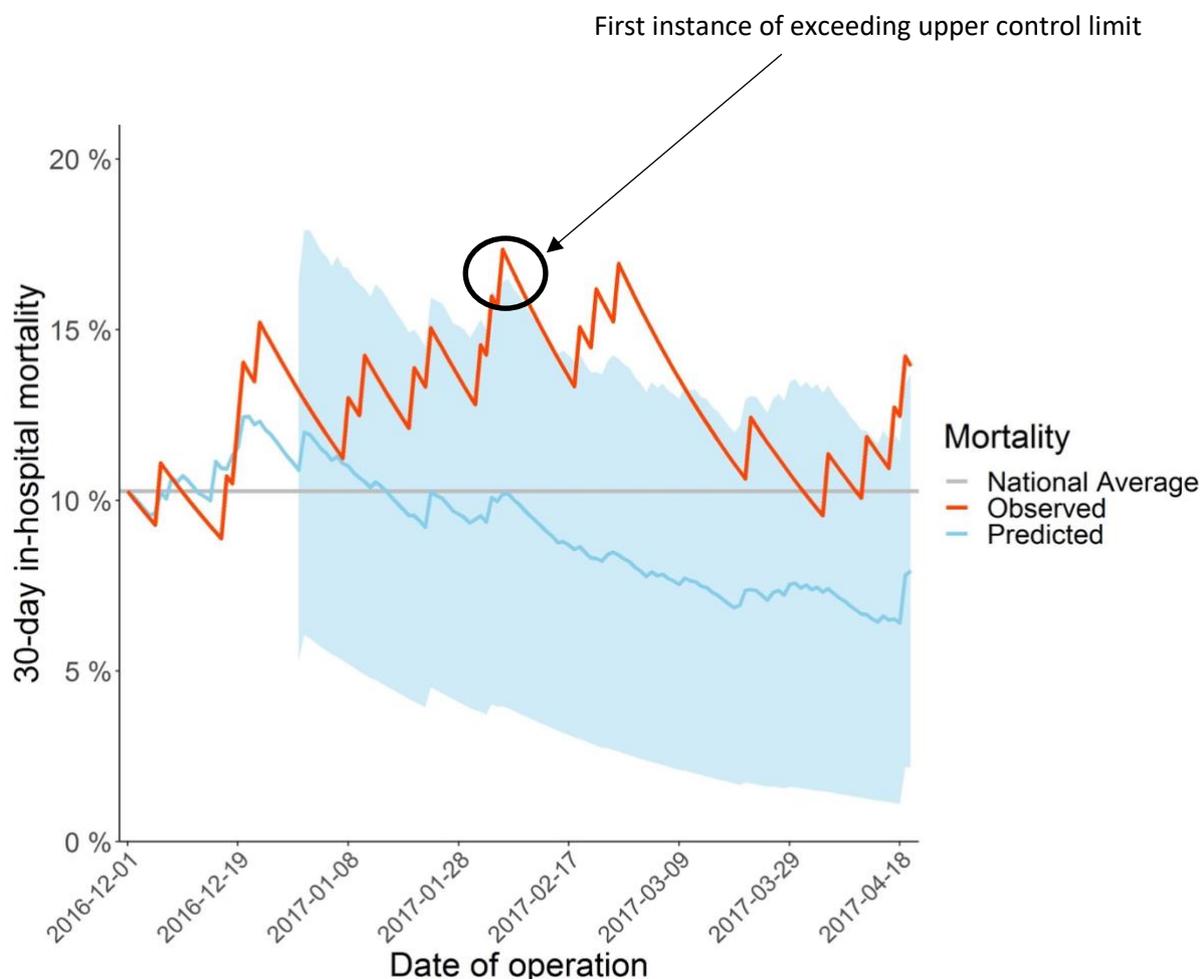
We first look at an example of a EWMA chart that does not signal a cause for concern.



In this hypothetical hospital, the **predicted mortality rate** is slightly above the national average for much of the time. So this hospital may have a casemix that is a little higher-risk than the national average. The **observed mortality rate** remains within the control limits throughout the period, and stays near or below the **predicted mortality rate** for much of the time. So there is no reason to suggest, from these data, that this hospital is performing worse or better than the average.

Example 2: A need to investigate

We now look at a EWMA chart that signals a need to investigate whether causes for an unusually high mortality rate can be identified.



In this hospital, the **observed mortality rate** exceeds the upper control limit in mid-January 2017. Possible reasons should be investigated immediately. (See our separate guide on "Investigating variation".) Although in this chart the observed mortality rate subsequently reduces and moves back within the control limits, nonetheless the alert should not be ignored.

Moreover, the **observed mortality rate** exceeds the upper control limit again in February 2017, and then remains above the control limit for around two months. A new investigation should then be conducted, or the existing investigation should be widened to take into consideration all recent patient deaths.

In this example, the EWMA chart may help guide some aspects of the investigation. This hospital's mortality rate is above the national average for much of the time from February to April, but the predicted mortality is below the national average. So actual mortality is high despite a relatively low-risk casemix.

If the EWMA chart shows that mortality is above the control limit, does this mean that my hospital is performing poorly?

Not necessarily. There are several types of reasons why a control limit might be exceeded.

1. **Random variation.** Both the observed and predicted mortality rate fluctuate randomly to some extent. Most of the time, random fluctuation is small, but occasionally it can lead to a control limit being exceeded – by ‘bad luck’, as it were. If we run the EWMA chart for long enough, then even if your hospital performs exactly as predicted, bad luck is certain to occur at some point. That is, sooner or later the mortality rate will exceed the control limit just by chance. Any control chart (EWMA or otherwise) will sometimes lead to false alarms of this sort.
2. **Inaccuracies or gaps in the data.** The EWMA chart cannot be more accurate than the data that are used to draw it. Thus, a control limit may be exceeded due to problems with the data. For example, the data your hospital has submitted up to a certain point in time may not contain all relevant patients, or all relevant information about the patients. Also, some information may be incorrect: for example, some deaths may not be correctly recorded, or some measurements used in the NELA risk prediction model may be inaccurate.
3. **NELA risk prediction model.** The NELA risk prediction model has shown to be well calibrated and to discriminate well between patients with different levels of risk. Nonetheless, it is possible that there are hitherto unidentified subgroups of patients for whom the NELA risk model is less accurate than for others. Hospitals whose patient population differs from that of other hospitals in ways not captured by the NELA risk prediction model may therefore be more likely to see their mortality rate exceed a control limit. This wouldn’t mean that the hospital is performing poorly, but would be due to residual inaccuracy in the NELA risk prediction model. We don’t know or suspect that such residual inaccuracies greatly affect the performance of EWMA charts, but we cannot rule out this possibility entirely.
4. **Hospital performance.** Problems with clinical care are just one of the set of reasons that should be suspected, and investigated, when mortality falls outside a control limit. See our separate guidance on “Investigating variation”.

What is the relationship between EWMA real-time monitoring of mortality, and the funnel plot of national adjusted mortality rates in the NELA annual report?

The retrospective funnel plot that is published with each NELA Annual Report plots each hospital's adjusted mortality rate against the caseload. It aims to identify hospitals that are 'in-control' (which means that the data suggest the hospital was performing approximately at the national average in that audit year) and hospitals that are 'outliers' (which means that the data look as though the hospital was performing either better or worse than the national average in that audit year). Hospitals that are identified as 'high outliers' are officially notified and have a duty to respond, as outlined in the NELA Outlier Policy. For an example, see the Fourth NELA Patient report (NELA Project Team 2018).

The EWMA chart has a very similar aim as the funnel plot: to assist a hospital in making sense of its mortality data in the context of a validated model for risk-adjustment and a comparison with national data. However, there is no outlier policy associated with EWMA charts. Hospitals are free to use them as they see fit. For recommendations, see our separate guidance on "investigating variation".

One way to use the EWMA chart may be as an early warning system: if a hospital exceeds a EWMA control limit, this might mean that it is 'on course' to be identified as an outlier in the funnel plot at the end of the year. On the other hand, if a hospital's EWMA chart consistently shows observed mortality below predicted mortality, it is unlikely to be an outlier in the funnel plot at the end of the year. However, there are several differences between the methodology of the EWMA charts and the methodology of the funnel plots, which mean that there may not be a perfect correspondence between the findings of the two methods. These differences are:

- **Mortality measure:** the EWMA chart uses 30-day in-hospital mortality reported by hospitals themselves, the funnel plot uses death registrations obtained from the Office for National Statistics to derive 30-day mortality. While these two measures agree in most cases, there will be some cases where they do not.
- **National average:** The national average mortality given in the EWMA chart is the previous audit year's national average, such that data from Year X are compared to the national average of Year X – 1. The funnel plot, on the other hand, compares data from Year X – 1 with the national average mortality of Year X – 1.
- **NELA Risk Score calculation:** The EWMA chart uses the published parameters from the NELA risk adjustment model to calculate patient mortality risk (Eugene et al 2018). The funnel plot updates the parameters every year, using all available patient information from the beginning of NELA data collection.
- **Missing value imputation.** In a small proportion of patients, some of the information needed to calculate the patient-specific mortality risk is not reported by hospitals. EWMA

chart and funnel plot differ slightly in how a risk prediction is derived in the presence of missing information.

References

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