

100 Apples Divided by 15 Red Herrings: A Cautionary Tale from the Mid-19th Century on Comparing Hospital Mortality Rates

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In 1863, Florence Nightingale argued that London hospitals were dangerous, especially compared with provincial facilities. She bolstered this contention with statistics published in William Farr's Registrar-General report, which claimed that 24 London hospitals had mortality rates exceeding 90%, whereas rural hospitals had an average mortality rate of 13%. Farr had calculated mortality rates by dividing the total number of patients who died throughout the year by the number of inpatients on a single day. When calculated as the annual number of deaths divided by the total number of inpatients during the year, the mortality rate of London hospitals was 10%. A raucous debate erupted in the London medical press over how best to calculate hospital mortality rates. Critics claimed that Farr had not adjusted for differences in severity of illness between urban and rural hospitals and that his figures would mislead the public. Farr and Nightingale, in turn, criticized the poor quality of hospital data. This story reinforces the need to understand the methodologic derivation of statistics intended to compare provider quality.

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Concerns about quality are increasingly surfacing as the U.S. health care system undergoes radical change. Although quality measures remain limited, many health care marketplace competitors, especially for-profit insurance plans, are leading the development of new approaches. Quality is central to the marketing of some providers and plans, which claim that improved quality decreases costs.

A worrisome byproduct of this commercial emphasis is the trend toward proprietary quality measures disseminated as "black boxes," with the clinical and empiric logic guarded as a competitive trade secret (1-5). Organizations claim to assess quality but reveal few details about their methods. Understandable documentation is also frequently unavailable for noncommercial approaches. Specific methodologic choices, however, can skew perceptions of provider performance. Even hospital mortality rates, a seemingly straightforward staple of many provider "report cards," can be modulated by the manner in which they are calculated (6, 7).

A provocative example of a methodologic choice that had substantial implications for assessing hos-

pital performance comes from mid-19th century Great Britain. This choice produced a distorted impression of hospitals, especially large urban facilities, as dangerous places that not only "did no good" but "positively did harm" (8). This misperception lasted more than a century. This historical example underscores the need to open black boxes and look inside.

The Calculation

In 1863, Florence Nightingale (1820-1910) published the third edition of her *Notes on Hospitals* (9), recommending fundamental changes in the configuration, location, and operation of hospitals to reduce the number of deaths caused by unsanitary conditions. Seven years earlier, Nightingale had returned from Crimean War service at British military hospitals, perhaps the first wartime celebrity created by the news media (10). As crafted by a correspondent from *The Times*, her image as a lone lady nursing sick soldiers by the light of her hand-held lamp earned Nightingale an admiring lifelong audience. This gentle, ministering angel persona, however, belied Nightingale's tough-minded, laser-focused administrative acumen: In 1855, 6 months after arriving in Scutari, Albania, she cut military hospital mortality rates from 42.7% to 2.2% (10).

Upon returning home, Nightingale continued to target military installations. Needing statistical help, she turned to William Farr (1807-1883), a physician and prominent social reformer who had done analyses for the Registrar-General since 1838. In 1856 they made a pact: Farr would assist Nightingale with army reforms, and Nightingale would aid Farr in his efforts to reduce the number of civilian deaths (11). In her 1863 *Notes on Hospitals*, Nightingale concentrated on civilian hospitals.

Farr and Nightingale believed that the dangers posed by urban mid-19th century hospitals were obvious, as shown by the number of deaths at the "106 principal hospitals of England" in 1861 (Figure 1). Most startling was the 90.84 "Mortality per cent. on Inmates" at 24 London hospitals. Taken from Farr's *24th Annual Report of the Registrar-General*, death rates were calculated as follows: total number of

Mortality per Cent. in the principal Hospitals of England. 1861.

	Number of SPECIAL INMATES on the 8th April, 1861.	Average Number of INMATES in each HOSPITAL.	Number of DEATHS registered in the Year 1861.	MORTALITY per Cent. on INMATES.
IN 106 PRINCIPAL HOSPITALS OF ENGLAND	12709	120	7227	56.87
24 London Hospitals	4214	176	3828	90.84
12 Hospitals in Large Towns	1870	156	1555	83.16
25 County and Important Provincial Hospitals	2248	90	886	39.41
30 Other Hospitals	1136	38	457	40.23
13 Naval and Military Hospitals	3000	231	470	15.67
1 Royal Sea Bathing Infirmary (Margate)	133	133	17	12.78
1 Dane Hill Metropolitan Infirmary (Margate)	108	108	14	12.96

Figure 1. Table published in the third edition of Florence Nightingale's *Notes on Hospitals* (9).

deaths at the hospital in 1861/number of patients at the hospital on 8 April 1861. Thus, the numerator reflected figures from an entire year, whereas the denominator encompassed a single day. Farr had calculated death rates per occupied hospital bed, not mortality rates per the total number of hospitalized patients.

This methodologic choice inflated apparent mortality rates. Not surprisingly, hospital mortality rates improved considerably when calculated as the annual number of deaths divided by the total number of inpatients treated during the year. By using this method, mortality rates in 1861 in the "general wards" at 14 London hospitals averaged 9.7% (12).

The Policy Context

British authorities had long collected information about mortality rates, primarily to track epidemic illness. Overwhelmed by plague-related deaths, Henry VII began gathering weekly "Bills of Mortality" in 1532 (13). Starting late in the 18th century, the massive social upheavals of the industrial revolution heightened this interest. As populations shifted from the countryside, amassing within congested industrial centers, statistics clearly showed egregious

public health consequences. By the 1830s, statistical societies had arisen throughout England, founded by civic and business leaders intent on quantifying the effects of these social changes. The archetypal member was "a liberal Whig, Unitarian, reform-minded" (11). These early Victorian statisticians viewed "facts" as the scientific means to prompt political change. Farr himself published the first Registrar-General reports on deaths in 1839, claiming that "these facts will [promote] . . . practical medicine" by identifying areas rife with disease (14).

British hospitals had accumulated statistics on their patients since the 1600s. In Victorian England, hospital statistics served several purposes. Because hospitals were primarily charitable institutions serving the poor, statistics quantified for wealthy benefactors the results of their charity and encouraged new subscribers. As can be seen today, those paying for hospitals wanted to ensure that they were getting their money's worth. In addition, as noted in an 1863 report for the Medical Officer of the Privy Council (15), "the public as a rule still look to the death-rates of hospitals as the best indication of their relative healthiness."

Not all Victorians shared a passion for numbers. Social critic Charles Dickens parodied statistical fixations in his dark 1854 novel *Hard Times* in the

character of Thomas Gradgrind, eminent citizen of sooty Coketown, who intoned, "In this life, we want nothing but Facts, Sir; nothing but Facts!" Dickens believed that individual persons were lost among statistics. Nonetheless, Nightingale's experiences during the Crimean War had taught her that facts were the best way to prod recalcitrant military authorities into action (16, 17). She and Farr thus used statistics to wage their civilian reform campaign.

The Methodologic Context

Today, observers might view Farr and Nightingale as erring in their calculations or intentionally skewing statistics to bolster political arguments. In the 1860s, however, little consensus surrounded statistical techniques, let alone the manner in which hospital mortality rates should be calculated. Victorian statisticians emphasized subject content rather than methods, accepting "men of little mathematical ability" into their field (11). Although Quetelet (much admired by Nightingale) investigated the "law of error" in the early 1800s, the 20th century's standard statistical techniques and ways of thinking about error and uncertainty were decades away. For example, W.S. Gross proposed the *t*-test (under the pseudonym "Student") in 1908 (18), Fisher's refinement appeared in 1925 (19), and Pearson introduced chi-square goodness-of-fit tests in 1900 (20).

Hospitals calculated mortality rates in different ways to suit their particular goals (8, 15). The most effective way to skew statistics involved specifying the numerators of mortality rates. As the 1863 Privy Council report (15) noted,

In the majority of hospitals, it is . . . the custom to reckon among their deaths those who have been brought dead to the institution; but there are many hospitals where such cases are not reckoned, and there are some indeed where even those who die within 24 hours are, on the ground that they were moribund at the time of admission, excluded from computation.

Another factor skewed comparisons of mortality rates between urban and provincial hospitals. Many provincial hospitals explicitly refused patients with phthisis (tuberculosis) or fevers and the "dead or dying," whereas urban facilities took everyone (15). Urban facilities objected to being compared with outlying hospitals that excluded such patients. As the 1846 Glasgow Royal Infirmary report (8) stated, "the reception of moribund cases greatly swells the number of deaths recorded in the Hospital, and very materially increases the proportionate mortality thereby producing misconceptions in the public mind. . ."

As described below, Farr and Nightingale were

criticized primarily because of their denominator. Nonetheless, in the mid-19th century, some viewed the number of deaths per bed as an indication of the hospital's productivity—another measure to show charitable donors. A further rationale for calculating per-bed mortality rates was the notion that having low occupancy rates (low average daily census) was healthy, giving patients more space and lessening the fear of contagion. In his 1877 report on English hospital mortality, Lawson Tait, a fellow of the statistical society, emphasized this point by explicitly calculating rates by bed and by patients (21).

In 1865, surgeon Fleetwood Buckle raised concerns about biases from calculating per-bed mortality rates, especially when comparing rates across hospitals (22). Buckle was troubled about attributing deaths to unoccupied beds. In his pamphlet on the mortality rates for English hospitals in 1863, Buckle stated, "no 'bed-rate' has been given, as it is obvious that in many country hospitals, where perhaps only half the number of beds are occupied at a time, the rate would be much lower than it should be, while in others, where the beds are constantly full, it would be correspondingly high" (22). At least Farr had used occupied beds.

Nightingale herself wrote few original reports on statistical methods (23), focusing instead on graphic ways of presenting information. Nightingale nevertheless emphasized concerns about underlying data quality, generally viewing hospital-reported data with suspicion. With an eerily modern ring, she wrote,

. . . Accurate hospital statistics are much more rare than is generally imagined, and at the best they only give the mortality which has taken place *in* the hospitals, and take no cognizance of those cases which are discharged in a hopeless condition, to die immediately afterwards, a practice which is followed to a much greater extent by some hospitals than others.

We have known incurable cases discharged from one hospital, to which the deaths ought to have been accounted and received into another hospital, to die there in a day or two after admission, thereby lowering the mortality rate of the first at the expense of the second (9).

The Response

Today, hospital mortality rates exceeding 90% would prompt a swift and vigorous outcry from the popular press. Review of indexes to *The Times* from 1861 through 1865, however, found few articles about hospitals and none about controversies over Nightingale's publication and hospital mortality statistics. That debate occurred in the London *Medical Times and Gazette* and *The Lancet*, and the major critics were men practicing at urban hospitals (11).

An anonymous reviewer of *Notes on Hospitals*

began, "It is sad to see a work of so much value—full of such useful information—disfigured by a few serious and elementary mistakes. Much as all Medical men must appreciate the philanthropic labour of its authoress, it is a false kindness to pass erroneous views without protest" (24). The reviewer observed that, because the mortality rate table came from the Registrar-General, "perhaps Miss Nightingale can hardly be held responsible for it." He nonetheless excoriated the methods, noting,

The inmates of a single day are balanced with the deaths of a whole year, and no wonder the results are "striking enough." It is to be hoped there are valid reasons for giving to the world what seems to us a simple piece of arithmetical legerdemain. Surely it is the very essence of percentages and of averages (both, we believe, fruitful sources of error), that the figures dealt with should stand on one and the same bottom, and that deaths for one year should be compared with admissions or discharges for that period, and no other. There is something audacious in the last column of this table, where twenty-four London Hospitals are accredited with a "mortality per cent on inmates" of 90.84. No doubt it will be said this is the quotient of the figures employed; but we entirely deny their validity and the accuracy of the impression thus conveyed. The problem as here put is exactly that so often asked of forward schoolboys—What is the quotient of a hundred apples divided by fifteen red herrings (24).

Farr's arithmetic choices were slyly caricatured by John Bristowe, a prominent London physician, who showed that hospital "recovery" rates calculated using Farr's methods would range from 899.5% to 953% (25). Timothy Holmes, a London surgeon, indicated that by Farr's method, one hospital had a mortality rate of 130%, clearly a "misleading" figure (26).

Another anonymous critic objected to the absence of risk adjustment, viewing comparisons between inner-city and rural hospitals as hopelessly flawed: "Any comparison which ignores the difference between the apple-cheeked farm-laborers who seek relief at Stoke Pogis (probably for rheumatism and sore legs), and the wizzened [sic], red-herring-like mechanics of Soho or Southwark, who comes from a London Hospital, is fallacious" (27). Bristowe (25) concurred:

Has Dr. Farr . . . really overlooked the differences in relative severity of cases admitted into his different classes of Hospitals, the different relative length of stay of their inmates, the different numbers of patients treated in them in relation to the numbers of constantly-occupied beds? Has he no suspicion that his death-rate is determined almost wholly by these causes?

Bristowe also questioned how the public would interpret Farr's mortality rates: "That Dr. Farr understands the mathematical meaning of his figures no one will doubt; but that the majority of his readers understand them neither in this sense nor in any other, and are utterly misled by them, is certain" (25). Bristowe directly challenged the motiva-

tions of Farr and Nightingale, stating that when they "try to mislead others into the belief that the unhealthiness of Hospitals is in proportion to Dr. Farr's death-rates of Hospitals, we are bound to protest against the whole matter as an unfounded and mischievous delusion" (25).

The Defense

In her book, Nightingale clearly argued that "in all hospitals, even in those which are best conducted, there is a great and unnecessary waste of life . . ." (9). In the Crimean War, statistics had helped her overcome the resistance of military officials. Perhaps anticipating similar hurdles in her civilian crusade, Nightingale chose the statistics that best supported her case.

Medical leaders did sometimes minimize concerns about hospital mortality rates. In the 1860s, eminent physician Sir John Simpson railed against "hospitalism"—the "hygiene evils" of hospitals. Finding much higher mortality rates from amputation at hospitals than in "country practices," Simpson asked, "Do not these terrible figures plead eloquently and clamantly for a revision and reform of our existing hospital system?" (28). His colleagues apparently remained unconvinced:

. . . I have conversed on many occasions with many medical men upon this subject. I have found, however, that to most professional minds it seemed to be altogether a kind of medical heresy to doubt that our numerous and splendid hospitals for the sick poor could by any possibility be aught than institutions as beneficial in their practical results as they were benevolent in their practical objects (29).

Although Nightingale was a celebrity, as a non-physician, she may have felt even less able to motivate change (8, 17).

Two weeks after the review of *Notes on Hospitals*, the *Medical Times and Gazette* published Farr's response. He took exception to an anonymous reviewer "who could treat a lady roughly" (30), although he later accurately acknowledged that Nightingale was "well able to defend herself" (31). Farr argued that if hospitals would provide accurate figures on the number of patients who were treated and died, few disputes would arise. He did not refute specific attacks on his calculation, instead emphasizing a fundamental reservation about most mortality rate calculations:

This [Farr's approach] is one method; there is another which is less correct, but more common. The deaths are divided by the mean number of cases admitted and discharged . . . The defect of this method lies in this: it does not take the element of time into account, which is important, as it so happens that cases are scarcely ever admitted as in-patients of Hospitals at their ori-

gin, and that many cases are discharged from Hospital before they have terminated (30).

Thus, Farr wanted to hold constant the window of observation, saying, for example, that it was unfair to compare death rates at St. Thomas's in London (average inpatient stay, 39 days) with rates at two Dublin hospitals (average stay, 27 days) (30). At least, Farr argued, his calculation was clear in exactly what it was observing.

One year later, when the Statistical Society, with Farr as treasurer, published hospital mortality rates for 1863, the rates were calculated according to the following formula: annual number of deaths/annual number of admissions + (number of patients at the beginning of the year - number of patients at the end of the year) (12). The publication noted that lengths of hospital "residence" were very long, averaging 30 days for 14 London hospitals. Despite this methodologic shift, Farr continued using statistics to urge reform, writing to Nightingale in 1864, "What are figures worth if they do no good to men's bodies or souls?" (17).

Discussion

The statistical arguments between Farr and Nightingale and their critics arose against the backdrop of a more fundamental debate between the "contagionists" and "noncontagionists" that had begun in the 1830s over causes of hospital deaths (11). Nightingale clung tenaciously to the central role of sanitation and miasmas (noxious vapors spreading disease), fiercely resisting the increasingly popular "germ theory." She advocated architectural changes to allow more air circulation and shifting hospital sites to fresher outlying environments as the way to reduce the number of deaths, and she downplayed the benefits of antiseptic techniques. Farr was torn between his allegiance to Nightingale and his growing acceptance of the germ theory. In the end, statistical evidence tipped Farr into the contagionist camp and distanced him from Nightingale; his final conversion was confirmed by observing the 1866 cholera epidemic (11).

Ironically, however, in the ensuing decades, Nightingale's voice sometimes rose over that of her methodologic critics. The statistical debate in the *Medical Times and Gazette* and *The Lancet* receded, whereas *Notes on Hospitals* remained much read. Nightingale's proposals for changing ward configuration and hospital location were widely adopted and reduced the number of hospital deaths. Nightingale's view that urban hospitals were dangerous was shared by others for more than a century (8).

Victorian statisticians such as Farr and Nightin-

gale were almost religiously zealous, aiming to introduce the certainty of scientific rigor into political discourse. These statisticians viewed any aspersions on their integrity as outrageous; Holmes wrote that conducting statistical analyses "really intended to bolster up a private scheme" was a "piece of personal dishonesty" (32). Today's public no longer views statisticians as seekers of truth. Especially in today's political arguments, statistics are available to prove any point. Farr took his figures from public documents, and he was open about his methods—his calculations were not a black box. To interpret his figures, however, one had to understand how they were calculated and the consequent methodologic implications. Today, many users of statistics immediately seek "bottom lines" that advance their views; organizations generating statistics frequently withhold their methods from public scrutiny.

Nonetheless, points raised in the debate following Nightingale's publication precisely parallel themes cited frequently about today's efforts at measuring provider performance, including the requirement for severity or risk adjustment (1-4); the need to hold windows of observation constant (such as examining mortality 30 days after admission rather than in-hospital deaths [33]); suspicions about data quality (34); concerns about providers avoiding high-risk patients because of fears of public exposure (35); and reservations about the public's ability to understand reports on provider performance (36). At various times since the mid-1980s, each concern has been raised about highly publicized provider performance reports in the United States, such as the Health Care Financing Administration's publications of individual hospital mortality rates for Medicare (37) and reports in New York (36, 38) and Pennsylvania (1, 7, 39) on hospital- and physician-specific mortality rates for coronary artery bypass graft surgery.

The statistical methods used in these high-profile performance reports for comparing hospital mortality rates have frequently generated esoteric debates among methodologists, but even such basic issues as specifying numerators and denominators remain controversial. For example, in comparisons of rates of death from coronary artery bypass, one particularly problematic issue is how to handle patients transferred from other acute-care facilities. According to the June 1995 Pennsylvania coronary artery bypass hospital mortality report (39), 12 of 227 patients at a prominent academic center died, compared with the predicted 2 to 11 deaths. Hospital representatives argued that this higher than expected mortality rate was due to transfers: Fifty-two percent of their patients having bypass surgery were transferred from other institutions, some from facilities with open-heart surgery capabilities.

Table 1. Example of Calculating Screening Mammography Rates for Two Health Plans

Variable	Health Plan A	Health Plan B
Older women enrolled, <i>n</i>	10 000	10 000
Older women who saw their primary care physicians during the year, <i>n</i>	5000	5000
Older woman receiving screening mammograms, <i>n</i>	4000	4000
Calculation approach chosen by each plan	4000 ÷ 10 000	4000 ÷ 5000
Screening mammography rates calculated by each plan, %	40	80

Another example involved a Massachusetts hospital report card produced by the *Boston Globe* using data annually produced by hospitals and submitted to the state. Because of a specific attribute of their severity adjustment methods, the *Boston Globe* excluded from their mortality rate calculation all persons dying within 2 days of hospital admission. The reporters further rationalized that patients who died within 2 days would probably have died anyway, regardless of the quality of hospital care. Their strategy had obvious implications for comparing mortality rates across hospitals (40).

Fortunately, most government-sponsored reports have technical appendices that describe their methodologic black boxes. Even the *Boston Globe* revealed, in fine print, their exclusion of early deaths. Concerns arise, however, with the increasing number of proprietary quality measures that do not detail their methods (1-7). In addition, calculating hospital mortality rates is easier than producing provider performance reports for populations (for example, beneficiaries of specific insurance plans). For populations, specifying numerators and denominators for calculating rates is often challenging. Nevertheless, knowing the manner in which rates are calculated is essential to understanding comparisons across populations (see example in Table 1). Otherwise, grossly misleading impressions about provider performance could arise.

In fairness to Nightingale's substantial contributions, one postscript is essential. Although Nightingale drew heavily on mortality rates to further her arguments, she recognized that counting the number of deaths neglected the main goal of hospitals. As she noted,

If the function of a hospital were to kill the sick, statistical comparisons of this nature would be admissible. As, however, its proper function is to restore the sick to health as speedily as possible, the elements which really give information as to whether this is done or not, are those which show the proportion of sick restored to health, and the average time which has been required for this object . . . (9).

Today, most would agree. Nevertheless, 130 years after Nightingale's observations, information on pa-

tients' "health" after medical encounters is rarely available.

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