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Reviews and Commentary

A NOTE ON THE HISTORY OF THE CALCULATION OF HOSPITAL STATISTICS

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There is a continuing debate in the field of hospital infectious disease epidemiology about the correct way to calculate nosocomial infectious disease morbidity and mortality. On the one hand, there are the traditionalists who stick to common use and ease of understanding and divide the number of infected patients by either the number admitted or the number discharged during the period of observation (1). However, others, generally more mathematically inclined, never seem to tire of pointing out the shortcomings of this type of denominator (there is little quarrel with the numerator). They offer alternatives, the main one being to calculate the rates per patient-time of stay, i.e., per patient-day or patient-week (2, 3). Another alternative, especially in the context of clinical studies, is to calculate the rates per patients at risk (i.e., from time of admission).

The purpose of the present paper is to indicate the ancientness of part of the problem. In 1860, Florence Nightingale, in an effort to bring about a plan for hospital

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sanitary reforms, proposed at the International Statistical Congress in London (4) a uniform plan to obtain hospital statistics. The abstract submitted by Nightingale was reproduced in the Proceedings of the Congress, and an appendix in the same volume contained the registration form she proposed together with worked out examples on the statistics of the University College Hospital in 1859 and St. Thomas' Hospital in 1858. Her abstract, written in forceful language, began with the memorable line: "Up to the present time the statistics of hospitals have been kept on no uniform plan" (4, p. 63). In the abstract, Nightingale expressed the belief that the collection of hospital statistics "would enable the value of particular methods of treatment and of special operations to be brought to statistical proof" (4, p. 63), and that "the sanitary state of the hospital itself could likewise be ascertained" (4, p. 63). In the appendix, she indicated that seven elements were required to "enable us to calculate the results of hospital experience... 1. Remaining in hospital on the first day of the year. 2. Admitted during the year. 3. Recovered or relieved during the year. 4. Discharged incurable, unrelieved, for irregularities, or at their own request. 5. Died during the year. 6. Remaining in hospital on the last day of the year. 7. Mean duration of cases in days and fractions of a day" (4, p. 65).

The proposed registration form would allow collection of this information for each separate disease entity. Nightingale acknowledged the help of William Farr, the pioneering figure of vital statistics and epidemiology, who was the Superintendent of the Statistical Department of the Registrar General's Office for England (5). Farr's help seems to have been twofold. First, the form proposed by Nightingale was qualified as "essentially the same as that used by the Registrars General of the United Kingdom" (4, p. 65). Second, the tabular abstracts for the two hospitals were "prepared under the direction of Dr. Farr" (4, p. 65) from the data furnished by the hospitals; these data concerned only overall mortality (or recovery). In the worked out examples, the mortality (and recovery) are calculated for the two hospitals, for men and women separately, and per five-year age group. For all of these, two types of numbers were given, however. First, the mortality (or recovery) was presented as a "Proportion of Deaths per Cent. of Numbers constantly sick," and, second, as a "Proportion of Deaths per Cent. of Numbers treated" (4, p. 68). In both numbers, the numerators were the same. It was the denominators that were different. Of the first denominator, it is said,

> The number of beds constantly occupied may be obtained by taking the mean of the numbers remaining at the beginning and the end of the year, if the hospital has been fully occupied; or the mean of the numbers remaining at the beginning and the end of each quarter; or oftener, if the hospital be irregularly occupied; or, the total number of days spent in hospital by all the cases during the year might be obtained; and by dividing the sum by 365, the mean daily sick would be arrived at. (The total daily 'diets' issued during the year divided by 365 would give the same result) (4, p. 66).

This is a masterly short description of the two ways to calculate the first type of denominator, the patient-time spent in hospital. The first mode of calculation, the averaging of the population present, is the same as was used by the Registrar General for demographic purposes, and the second, counting days, is the same as that used in smaller scale epidemiologic cohort studies.

As indicated in Nightingale's text (4), and as firmly established in modern epidemiologic theory, they are equivalent (6). The unit of patient-time resulting from the calculation was the patient-year.

Of the second denominator, it is said, "The 'sick treated' during the year may be obtained by taking the mean of the admissions, and of the discharges of all causes, including deaths" (4, p. 66). This description will at once be recognized by those who stick to common usage in the calculation of nosocomial infections.

Using his privileges, William Farr commented upon these hospital statistics and their use in the Twenty-fourth Annual Report to the Registrar General, concerning the causes of death in England in 1861 (7). Besides strongly endorsing the idea that such statistics should be obtained and tentatively demonstrating some conclusions as to the greater sanitary status of small hospitals in small towns, Farr also offered a paragraph about the calculation:

> The hospitals are filled by a succession of inmates, who remain for a time varying from a day to a month or a year, and the mortality is often given as so many deaths per cent. on the cases treated. The mean term of treatment varies in different hospitals; in many it averages 36.5 days, or the tenth part of a year. Assuming that term of treatment to be applicable, the mortality of the cases in these hospitals was 5.687 per cent. in 36.5 days; or the hospitals to every 100 beds occupied, had nearly 57 deaths annually (7, p. 423).

The virtuoso statistician here offered a third (approximate) way to calculate patient-time spent in hospital, using the average duration of stay. Apparently, however, Farr sided with the first denominator of the Nightingale paper and frowned upon the second. Indeed, it is difficult not to be tempted to recognize Farr's hand in the description of the patient-time denominator in Nightingale's paper; the intrinsic properties of calculations with person-time were well-known to him (8). As recently described by Eyler in his study of Farr's work in relation to Victorian social medicine (9), it was not the first time that Farr had proposed population-time as the denominator for hospital statistics. Farr's

earlier proposals had repeatedly been met with opposition from the medical establishment, however, because the rates with person-time as denominator often became much larger than when calculated with cases admitted or discharged, e.g., when, in a tuberculosis ward, more than one patient had died in a given bed in a single year (9).

The Nightingale paper was discussed in 1947 in a talk given by Greenwood (10), the first professor of epidemiology at the London School of Hygiene and Tropical Medicine, who, besides his direct contributions to the epidemiology of infectious diseases, made many scholarly contributions to the history of the subject (11). About both death rates presented by Nightingale, Greenwood sternly commented: "Such ratios are, of course, only index numbers, and their affinity to the death-rates of ordinary practice is remote" (10, p. 99). Further on, Greenwood hinted at a dispute between Farr and Nightingale: "Farr, who spoke appreciatively of Miss Nightingale's proposal, tentatively suggested relating the deaths from a disease to the units of time under treatment; this, however, is still only an index number which *may* give a false impression" (original italics) (10, p. 99). Presumably, some of the subtlety of the Nightingale-Farr argument in the paper to the International Statistical Congress and in the later comments by Farr have escaped Greenwood; the later proposal by Farr was in fact identical with the "constantly sick" or "beds constantly occupied" denominator of the Nightingale paper, which was in turn identical with usual practice of the Registrar General. Yet, Greenwood clearly foresaw that even if "rightly" calculated, comparisons between different hospitals, as proposed by Nightingale and attempted by Farr in his comparison between small town and large city hospitals, might still be fraught with danger because of the different types of patients admitted. In his own words: "... the universe of discourse was not so simple as, perhaps, Florence Nightingale supposed. Hospital patients are not a random sample of the population and diseases treated in hospital not a random

sample of human ailments" (10, p. 99). It should be added that the near impossibility of the comparison had also not escaped contemporaries of Nightingale and Farr, and has provoked much criticism, especially of Farr (9). Still, Greenwood ended his paper by expressing his admiration, pointing his 1948 audience to the relevance of the historic source: "Now there is good reason to believe that hospital statistics will be really utilized scientifically on a nationwide scale, not *quite* a century after Florence Nightingale made the suggestion" (original italics) (10, p. 100).

It is amazing and amusing that even today, in the era of computerized hospital data bases, so little has changed in the basic issues. The fancier nosocomial infection data base programs nowadays allow for different denominator preferences by setting up denominator tables in which one can enter numbers discharged or admitted or patient-days of stay. As far as the comparison of patient outcomes between different institutions is concerned, the tools of multivariate analysis, aimed at adjusting for different patient characteristics, are just beginning to emerge (12), and the collection of the necessary data is judged to be a heavy, nonroutine, research burden (13).

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