Measures Of Disease Frequency

Lecture 2: Mortality Measures & Survival

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Learning Objectives

By the end of this lecture, the students will be able to:

1. Realize the difference between disease morbidity and mortality
2. Define the Mortality rate and classify it
3. Calculate different mortality rates
4. Understand the concept of survival analysis
5. know how to interpret survival analysis data

Morbidity Vs Mortality

- The two most commonly used measures for epidemiological surveillance are **morbidity** and **mortality**.

- **Morbidity** is the state of being symptomatic or unhealthy due to a disease or condition. It is usually represented or estimated using prevalence or incidence.

- **Mortality** is related to the number of deaths caused by the health event under investigation.

Mortality Rate

A broader term that includes any rate measuring deaths in a population.

<u>It can refer to:</u>

- **Crude mortality rate**
- **Age-specific mortality rate**
- **Cause-specific mortality rate**
- **Maternal, infant, neonatal mortality rates,** etc.

Commonly Used Measures Of Mortality:

Crude Mortality Rate

It is the mortality rate from all causes of death for a population.

Numerator: Total number of deaths during a given time interval

Denominator: Mid-interval population

Crude Mortality rate=

$$\frac{\text{Total number of deaths during a given time interval}}{\text{Mid-interval population}} \times 10^n$$

- Where $10^n=10^3$ or 10^5

For example, suppose that a total of 3,000,000 deaths occurred in 2020. The estimated population was 400,000,000 at the midpoint of 2020. Therefore, the crude mortality/crude death rate in 2020 was $\frac{3000000}{400000000} \times 100{,}000=750$, or 750 deaths per 100,000 population.

Cause-specific Mortality Rate

It is the mortality rate from a specific cause in a population.

Numerator: Number of deaths assigned to a specific cause during a given time interval

Denominator: Mid-interval population

Cause-specific death rate=

$$\frac{\text{Number of deaths assigned to a specific cause during a given time interval}}{\text{Mid-interval population}} \times 10^n$$

- Where $10^n=10^5$

For example, in 2020, there were 91,799 drug overdose deaths in the United States. The midyear population of 2020 was 333,287,557. Therefore, the cause-specific (drug overdose) mortality rate was 27.5 per 100,000 population.

Mid-interval Population

The mid-interval population (also called mid-year population) is an estimate of the average population at risk during a specific period, usually taken at the midpoint of that period (e.g., June 30 for annual rates).

Why it's used?

Population size changes throughout the year due to births, deaths, and migration. Using the **mid-interval population** provides a more accurate estimate of the **population at risk** than using the beginning or end population alone.

Age-specific Mortality Rate

It is a measure of the frequency of a health event (such as deaths, disease cases, or births) within a specific age group in a defined population during a specified time period.

It shows how the rate of disease or death **varies across different age groups**, helping to identify which ages are at higher or lower risk.

Numerator: Number of events (e.g., deaths) in a specific age group during a given period

Denominator: population in the same age group during the same period.

$$\textbf{Age-specific rate} = \frac{\textbf{Number of events (e.g., deaths) in a specific age group during a given period}}{\textbf{population in the same age group during the same period}} \times 10^n$$

- Where 10^n = 1,000 or 100,000, depending on the event being measured.
- **For example:**

In Mansoura City in 2024: Number of deaths among people aged **45–54 years** = **60**

Mid-year population aged **45–54 years** = **12,000**

Age−Specific *Mortality Rate* $= \frac{60}{12{,}000} \times 1{,}000 = 5$ *deaths per 1,000 people aged 45–54 years.*

Infant Mortality Rate (IMR)

It is the risk of death during the first year of life.

Numerator: Number of deaths among children < 1 year of age during a specified time period

Denominator: Number of live births during the same time period

$$\textbf{IMR} = \frac{\textbf{Number of deaths among children < 1 year of age during a specified time period}}{\textbf{Number of live births during the same time period}} \textbf{ X } 10^{n}$$

$10^{n} = 10^{3}$

Example:

If 50 infants die before age 1 among 10,000 live births in a year, calculate the IMR?

$$\text{IMR} = \frac{50}{10{,}000} \times 1{,}000 = 5$$ **(So, IMR = 5 deaths per 1,000 live births)**

Maternal Mortality Rate (MMR)

It is the death of a woman while pregnant or within 42 days of the termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes.

Numerator: Number of deaths assigned to pregnancy-related causes during a specified time period

Denominator: Number of live births during the same time period

$$\text{MMR} = \frac{\text{Number of deaths assigned to pregnancy-related causes during a specified time period}}{\text{Number of live births during the same time period}} \text{ X } 10^n$$

- Where $10^n = 10^5$

Example:

If there are 50 maternal deaths and 100,000 live births in a year, calculate the MMR?

$$\text{MMR} = \frac{50}{100{,}000} \times 100{,}000 = 50$$

Case Fatality Rate

- Case fatality is a measure of disease severity and is defined as the proportion of cases with a specified disease or condition who die within a specified time. It is usually expressed as a percentage.

$$\text{Case fatality \%} = \frac{\text{Number of deaths from diagnosed cases in a given period}}{\text{Number of diagnosed cases of the disease in the same period}} \text{x100}$$

Case fatality rate :

- The case fatality rate is **used to link** mortality to morbidity.
- One function of the case fatality rate is to measure various aspects or properties of a disease such as its pathogenicity, severity or virulence .

It can also be used in poisonings, chemical exposures or other short-term non-disease cause of death.

Survival Analysis Basics

Survival Analysis: *time to event*

Survival data are concerned with the time it takes an individual to reach an endpoint of interest (often, but not always, death).

Examples:

1. Time from operation to death
2. Time from response till the recurrence of a tumor
3. Time from operation to discharge from the hospital.

TIME TO EVENT

It is characterized by the following two features.

1. It is the **length of time** for the patient to reach the endpoint, rather than whether or not she or he reaches the endpoint, that is of primary importance. For example, we may be interested in the length of survival in patients admitted with cirrhosis.

2. **Data may often be censored.**

- Survival times are calculated from some baseline date that reflects a natural 'starting point' for the study (e.g., time of surgery or diagnosis of a condition) until the time that a patient reaches the endpoint of interest.

- Often, we may not know when the patient reached the endpoint; only we know that she or he remained free of the endpoint while in the study.

For Example:

Patients in a trial of a new drug for HIV infection may remain AIDS-free when they leave the study. This may be because:

1. **The trial ended while they were still AIDS-free.**
2. **These individuals withdrew from the trial early, before developing AIDS.**
3. **They died of non-AIDS causes before the end of follow-up.**

❖Such data are described as **right-censored**. These patients were known *not* to have reached the endpoint when they were last under follow-up, and this information should be incorporated into the analysis.

❖Where follow-up does not begin until after the baseline date, survival times can also be **left-censored**.

Censoring occurs when **the exact event time is unknown**, but **partial information** about the event time is available. the two most common types are: **right-censoring** and **left-censoring**.

Type of Censoring	What We Know	Example	Meaning
Right-censored	Event **has not occurred** by last follow-up	Patient alive at study end	Event time > observed time
Left-censored	Event **occurred before** observation began	Infection before first test	Event time < observed time

Displaying Survival Data

A. A separate horizontal line can be drawn for each patient, its length indicating the survival time.

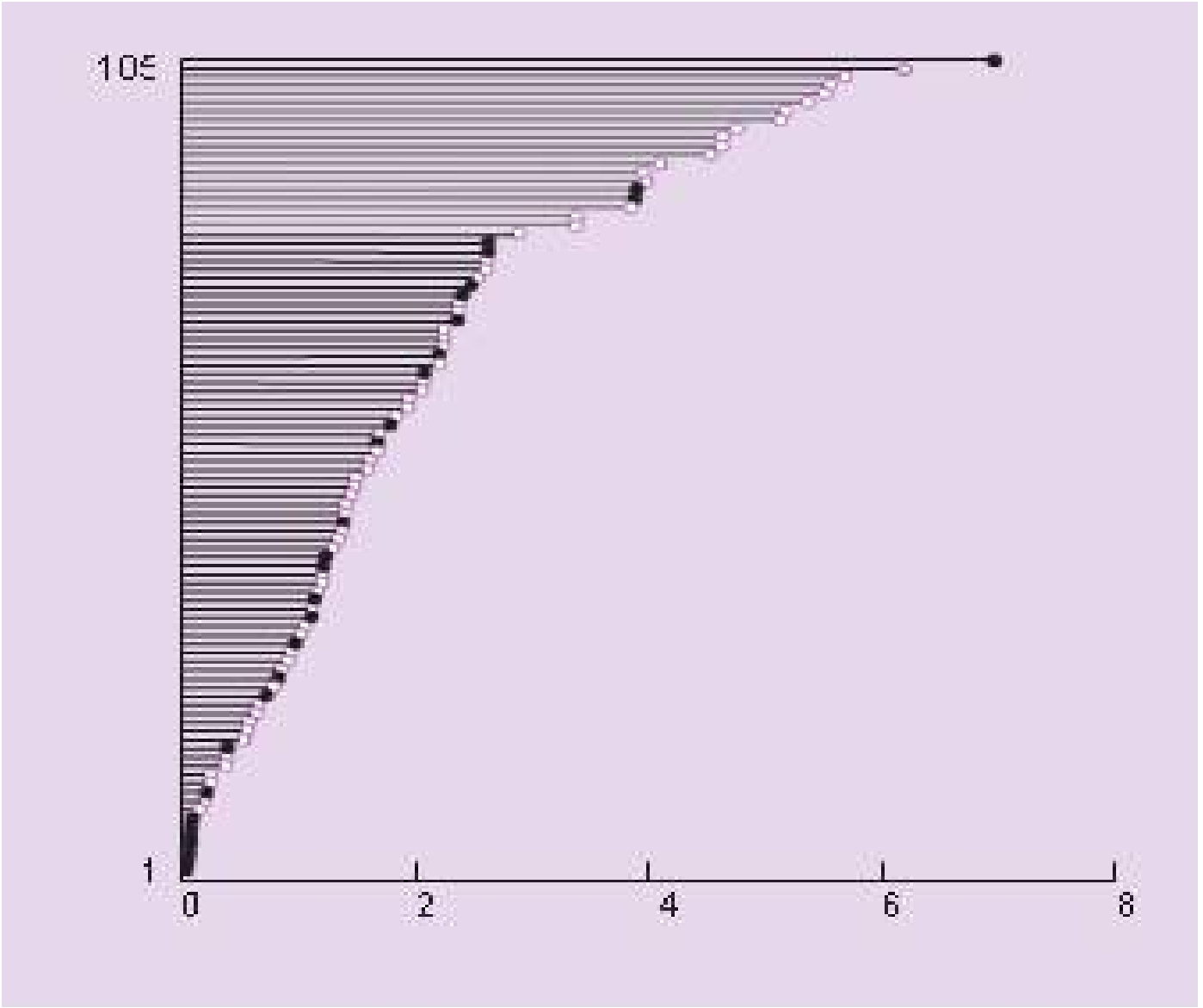
B. Lines are drawn from left to right, and patients who reach the endpoint and those who are censored can be distinguished by the use of different symbols at the end of the line (Fig.1).

C. However, these plots do not summarize the data, and it is difficult to get a feel for the survival experience overall.

Figure 1: Survival experience of 105 patients following admission with cirrhosis.

Filled blank circles indicate patients who died

Open circles indicate those who remained alive at the end of follow-up

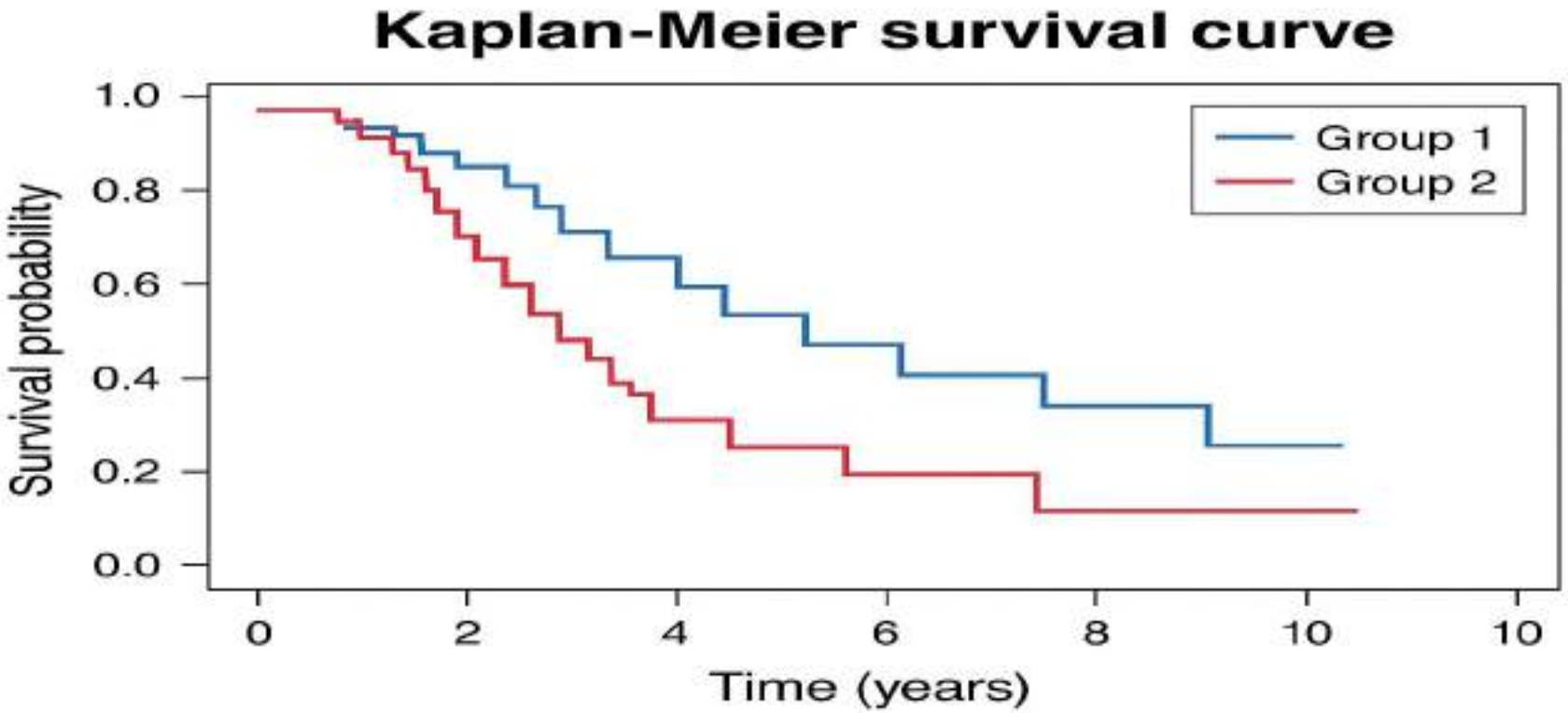


Survival Curve

A. A **survival curve**, usually calculated by the **Kaplan–Meier** method, displays the cumulative probability (the **survival probability**) of an individual remaining free of the endpoint at any time after baseline (Fig. 2).

B. The survival probability will only change when an endpoint occurs, and thus the resulting ‘curve’ is drawn as a series of steps, starting at a survival probability of 1 (or 100%) at baseline (time 0) and dropping towards 0 as time increases.

Figure 2: Kaplan–Meier curves showing the survival probability



Characteristics Of Survival Data:

A. Individuals do not enter the study at the same time.

B. When the study ends, some individuals still haven't had the event yet.

C. Other individuals drop out or get lost in the middle of the study, and all we know about them is the last time they were still 'free' of the event.

Problems Encountered In Survival Analysis

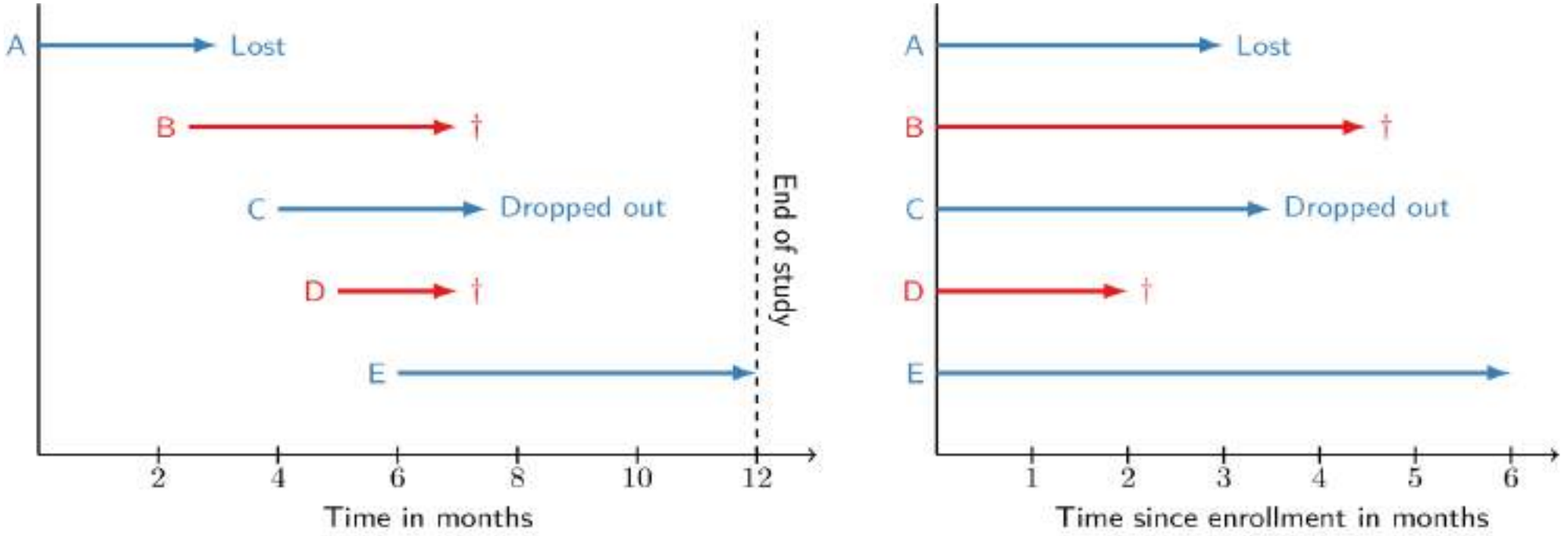
1. **Incomplete** follow-up can bias results.

2. **Informative censoring:** occurs when the reason for censoring is related to the likelihood of the event (e.g., liver transplant patients censored early have a different prognosis).

3. **Non-informative (administrative) censoring:** when follow-up ends because the study period ends.

Example:

Consider A Clinical Study That Has Been Carried Out Over 1 Year, As In The Figure Below.



Patient **A** was lost to follow-up after **3 months** with no event.

Patient B had an event 4.5 months after enrollment.

Patient **C** withdrew from the study **3.5 months** after enrollment.

Patient D experienced an event 2 months after enrollment.

Patient **E** did not have any event before the study ended (was followed up for **6 months**).

- The exact time of an **event** could only be recorded for patients **B** and **D**; their records are ***uncensored***.
- For the remaining patients, it is unknown whether they did or did not experience an event after the termination of the study. The only valid information that is available for patients **A**, **C**, and **E** is that they were **event-free** up to their last follow-up. Therefore, their records are ***censored***.

REFERENCES

1. A Textbook of Public Health Dentistry, CM Marya, **Jaypee Brothers Medical Publishers, 1st ED;** 2011 (**Chapter 2, Page 9-23**)

2. Medical statistics at a glance, Aviva Petrie and Carolen Sabin, **Wiley Blackwell Publisher. 3rd edition; 2009. (Chapter 44, page 133-135)**

Thankyou