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Plotting basic control charts: tutorial notes for healthcare practitioners

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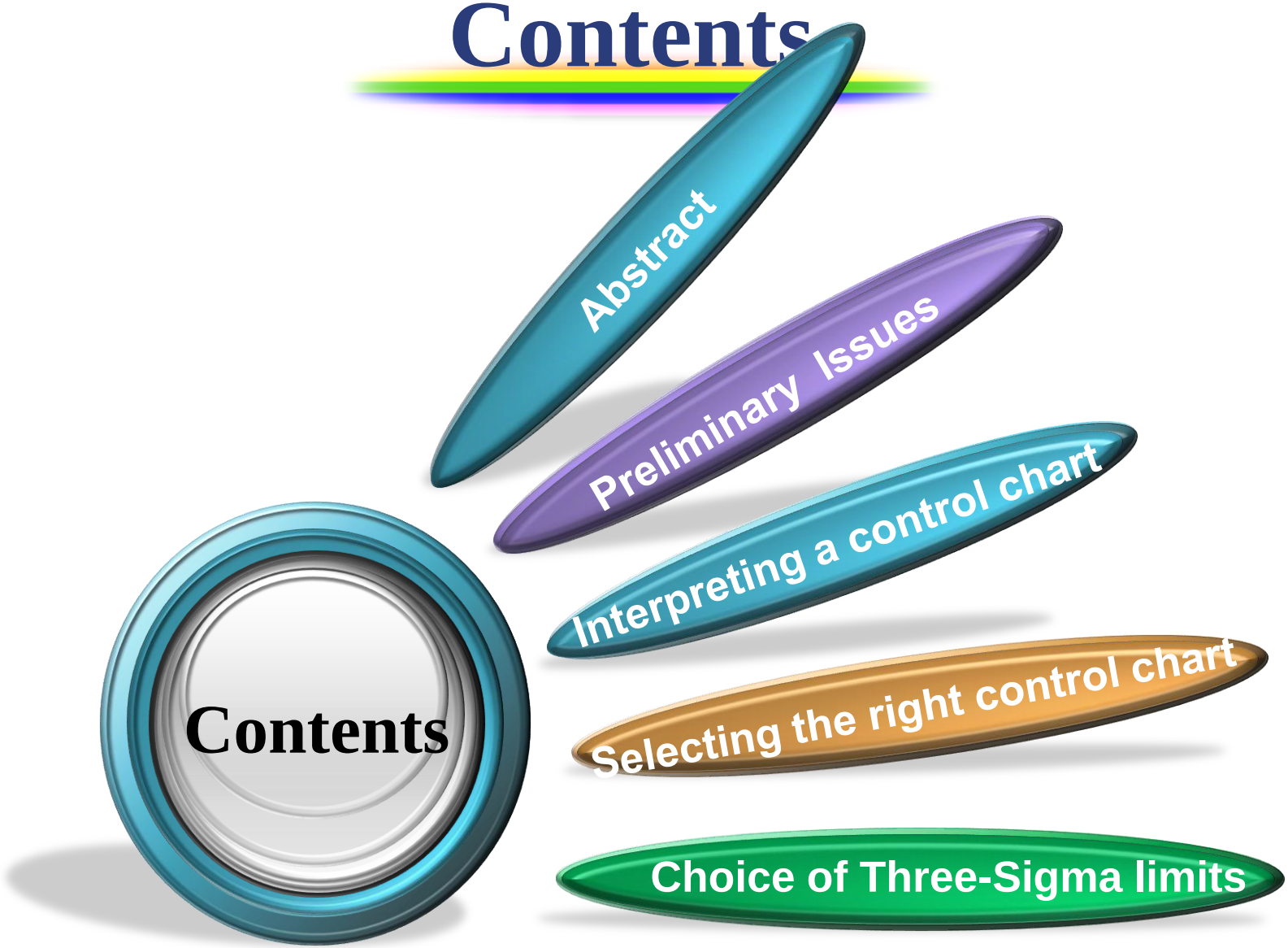
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Abstract

- 雖然SPC整體的理念不斷改善，但SPC在執行上還是需要各種管制圖。

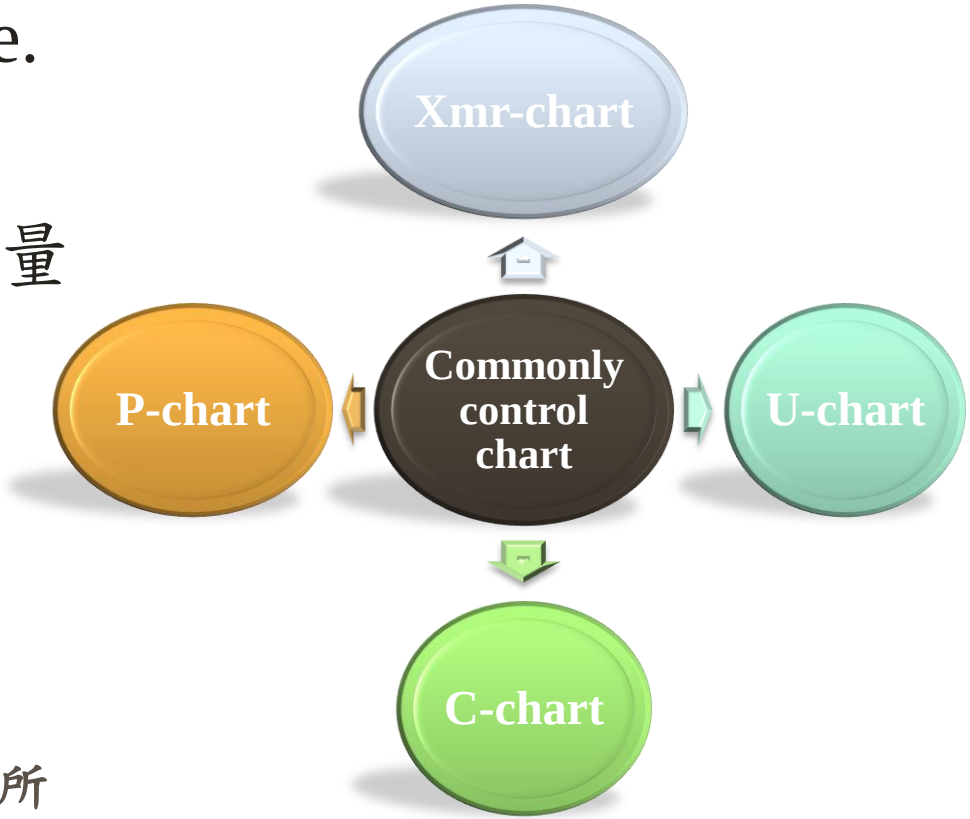
- 進而將SPC用於醫療照顧上，所以有必要去解釋涉及的問題以及管制圖的作法。

- With the help of illustrative examples, this paper aims to provide guidance on the selection and construction of control charts that are relevant to healthcare.

Abstract

- We use a tutorial-based approach to illustrate the selection and construction of four commonly used control charts (xmr-chart, p-chart, u-chart, c-chart) using examples from healthcare.

- 控制圖是一個數據的質量改進技術，可以用於提供持續改進。



Preliminary Issues

Before constructing control charts

- 確立目標和行動計畫，去進行如何調查在特殊原因數據點。
- 如何改善常見的過程變異原因。

- Furthermore, the data collection method should be designed to provide a dataset that adequately reflects the underlying process.

Preliminary Issues

- Measurement system analysis
  - includes measurement system linearity, stability, repeatability and reproducibility (GR&R),
- Sampling
- Rational subgrouping
  - X-bar 管制樣本間的變異
  - R管制圖 管制樣本內的變異
- Operational definitions

Preliminary Issues

Phase I

利用歷史數據提供一個基準，是評估穩定和檢測特殊原因，並估計參數的過程。

Phase II

基本假設機率分佈在適當的製程，隨時間持續監測數據的採樣。

Interpreting a control chart

- Several other tests can also detect signals of special cause variation based on patterns of data points occurring within the control limits.
  - A run of eight (some prefer seven) or more points on one side of the centre line.
  - Two out of three consecutive points appearing beyond 2 SD on the same side of the centre line (ie, two-thirds of the way towards the control limits).
  - A run of eight (some prefer seven) or more points all trending up or down.

Interpreting a control chart

Lee and McGreevey 2002	• 建議規則一要和趨勢規則連續六點上升或下降作結合。
Davis and Woodall 1988	• The trend rule does not detect trends in the underlying parameter.
Champ and Woodall 1987	• The CUSUM chart can work better than the runs rules in phase II.

Selecting the right control chart

- Two important types of data are:
  - Continuous data
    - 包含測量，如住院時間、轉診到手術的時間
    - **The xmr-chart**
  - Discrete data
    - 包含計數，如處方數量、病人等待的數量
    - **The p-chart, u-chartand the c-chart**

The xmr-chart

- Example：The systolic blood pressure (mmHg) readings for a patient (A Ibrahim, personal communication, 2005) in the morning over 26 consecutive days.

- The first step in producing an xmr-chart is to calculate the magnitudes of the differences between successive values of the data.

Reading number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Systolic blood pressure (mmHg)	169	172	175	174	161	142	174	171	168	174	180	194	161	181	175	176	186	166	157	183	177	171	185	176	181	174
Moving range		3	3	1	13	19	32	3	3	6	6	14	33	20	6	1	10	20	9	26	6	6	14	9	5	7

172-169=3

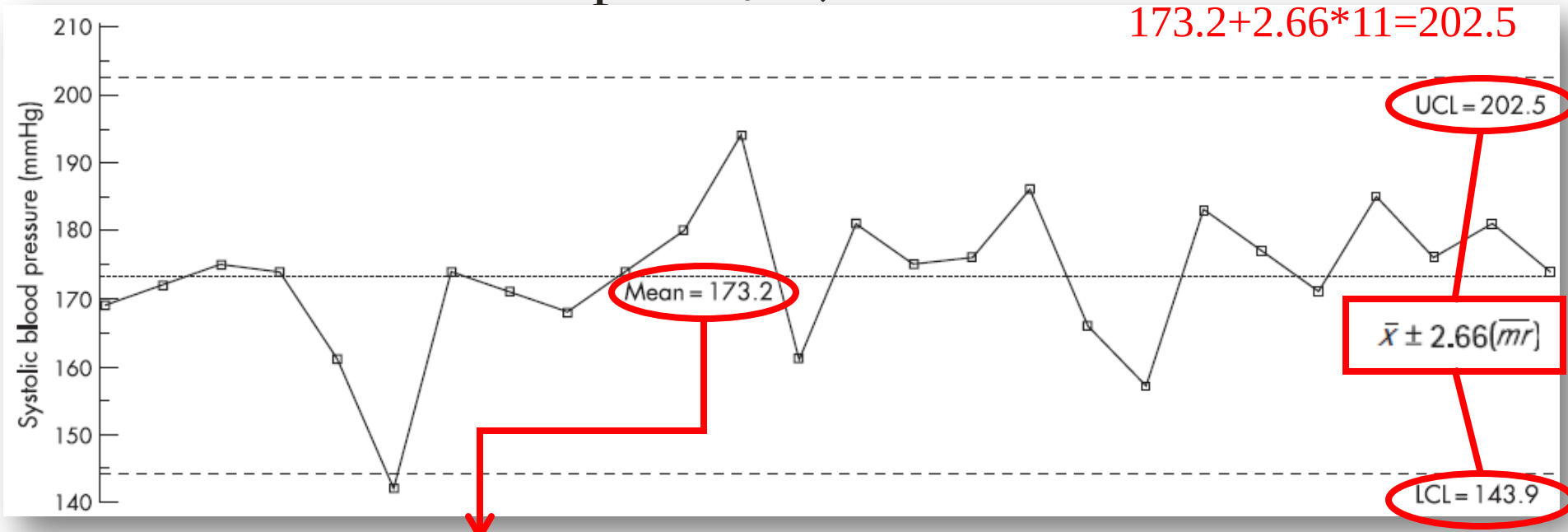
161-194=-33

PS => we drop the minus sign as we are only interested in the magnitude of the difference, not the direction.

The xmr-chart

- In the second step，建構x-chart

173.2+2.66*11=202.5



173.2-2.66*11=143.9

Mean, $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{4503}{26} = 173.2$

$\frac{\bar{R}}{d_2} = \hat{\sigma}\ \frac{3}{1.128} = 2.66$

Mean moving range,

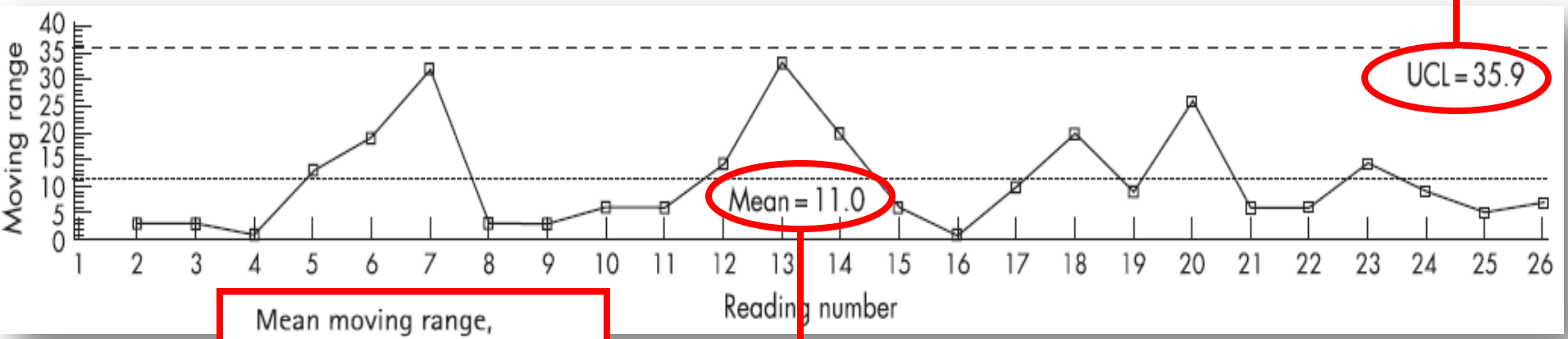
$\overline{mr} = \frac{\sum_{i=2}^{n} mr_i}{n-1} = \frac{275}{26-1} = 11$

The xmr-chart

- In the last step，建構mr-chart

$UCL = D_4 \bar{R}$

3.267*11=35.9



Mean moving range,

$$\overline{mr} = \frac{\sum_{i=2}^{n} mr_i}{n-1} = \frac{275}{26-1} = 11$$

The xmr-chart

- One characteristic => 時間順序數據應隨時間推移獨立評估。獨立是指不相關或自相關之間的關係或連續數據點。

Wheeler 1995

- Shows that even with moderate autocorrelations, the xmr-chart behaves well, but when the correlation is large then the control limits need to be widened by a correction factor.

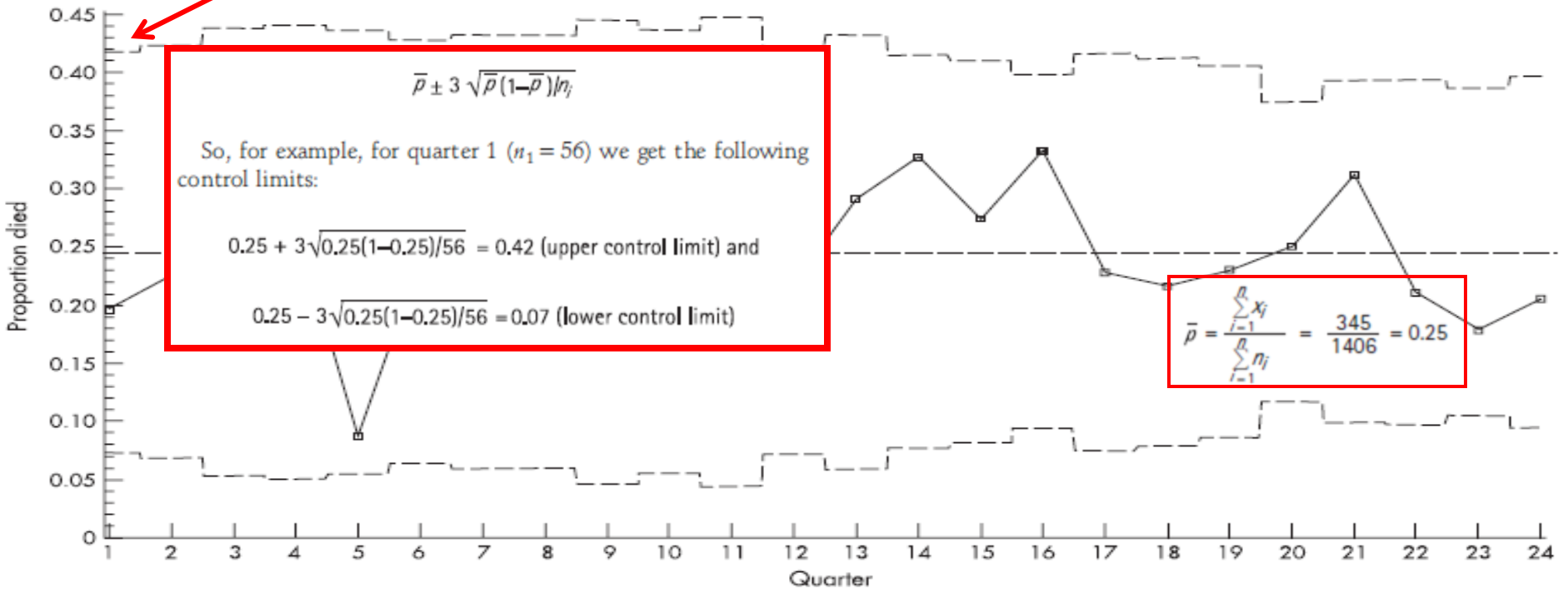
Maragah and Woodall 1992

- 即使是適度的自相關可以在範圍內產生不利影響性能的統計圖表，而時間序列為基礎的方法可能更適合自相關數據。

The p-chart

- Example： The data show the number of patients who were admitted with a fractured neck of femur and the number who died over 24 consecutive quarters (M Narayan-Lee, personal communication, 2006).

Quarter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Number of patients admitted with fracture neck of femur (n)	56	53	45	44	46	50	48	48	42	46	41	55	48	58	62	72	57	60	65	100	77	76	84	73
Number died (x)	11	12	11	12	4	12	15	13	9	14	10	12	14	19	17	24	13	13	15	25	24	16	15	15
Proportion died (x/n)	0.20	0.23	0.24	0.27	0.09	0.24	0.31	0.27	0.21	0.30	0.24	0.22	0.29	0.33	0.27	0.33	0.23	0.22	0.23	0.25	0.31	0.21	0.18	0.21
Centre line	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Upper control limit	0.42	0.42	0.44	0.44	0.44	0.43	0.43	0.43	0.44	0.44	0.45	0.42	0.43	0.41	0.41	0.40	0.42	0.41	0.41	0.37	0.39	0.39	0.39	0.40
Lower control limit	0.07	0.07	0.05	0.05	0.06	0.06	0.06	0.06	0.05	0.06	0.04	0.07	0.06	0.08	0.08	0.09	0.07	0.08	0.09	0.12	0.10	0.10	0.10	0.09



The p-chart

- The assumptions of the p-chart:
  - (a) Binary , 二進制 only have two states
    - eg, alive/dead, infected/not infected, admitted/not admitted, etc
  - (b) 有一個不斷發生的潛在可能性
  - (c) 互相獨立

- 反之，過度分散的數據將顯示違反假設b和c。

The p-chart

Xie et al 2002

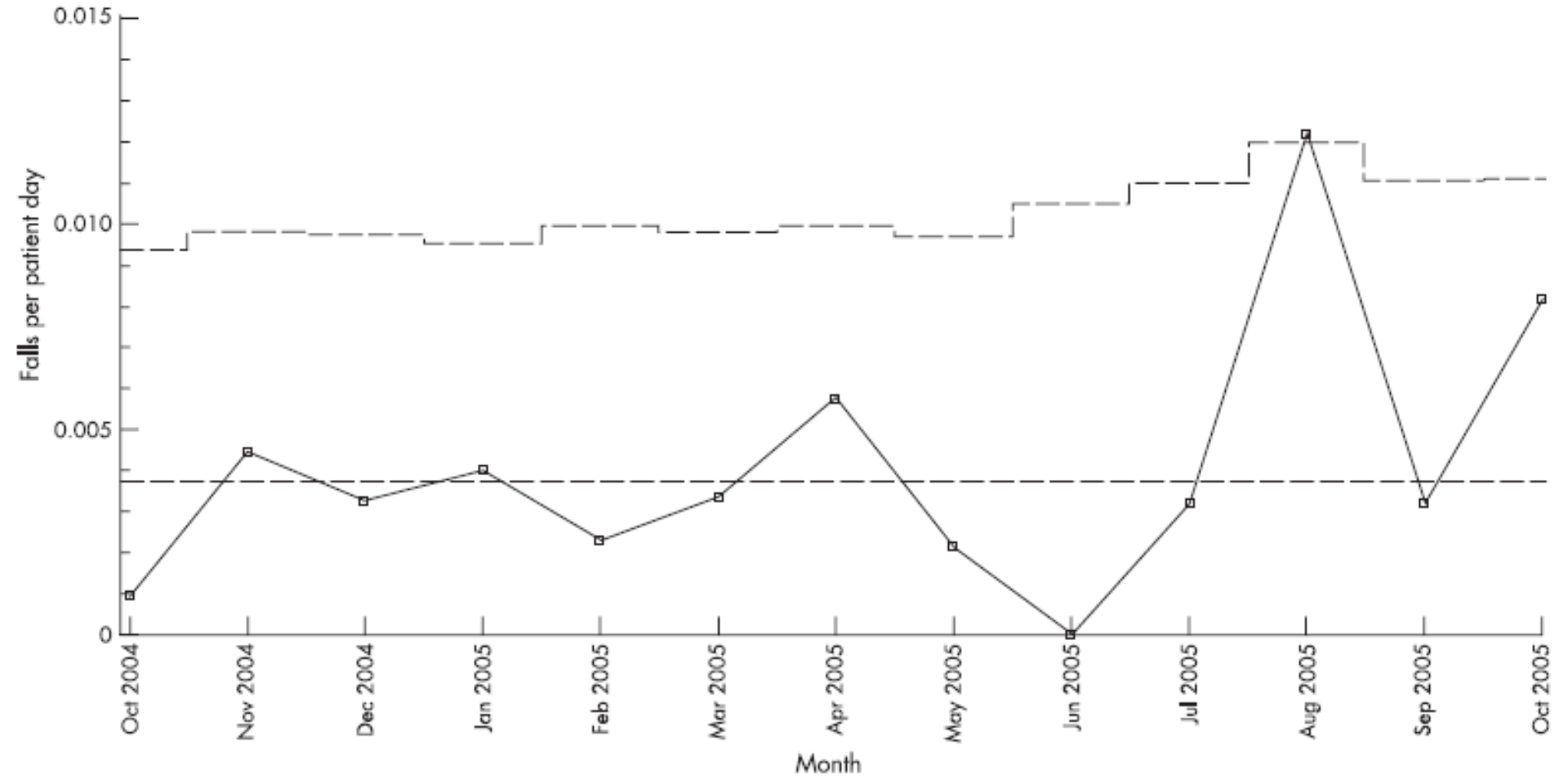
$n_i\bar{p}(1-\bar{p})>5$ and $0.1\leqslant\bar{p}\leqslant0.9$

- 因為在這些條件下二項分佈是相當對稱，所以Shewhart three-sigma的概念效果很好。

- A common application
  - Comparison of the performance of healthcare providers over a fixed period.

The u-chart

- Example： The number of falls in a hospital department over a 12-month period



0.00371 − 3√(0.00371/1048 = −0.00193 (lower control limit)

The u-chart

- The assumptions of the u-chart are that the events:
  - (a) 一次同時發生一個，沒有多個事件同時發生在同一個位置。
  - (b) 獨立的一個事件，並不會影響機率發生在同一時段或區域的任何事件。
- Using u-charts
  - 典型的低頻率事件
    - (eg, number of major complications following surgery)

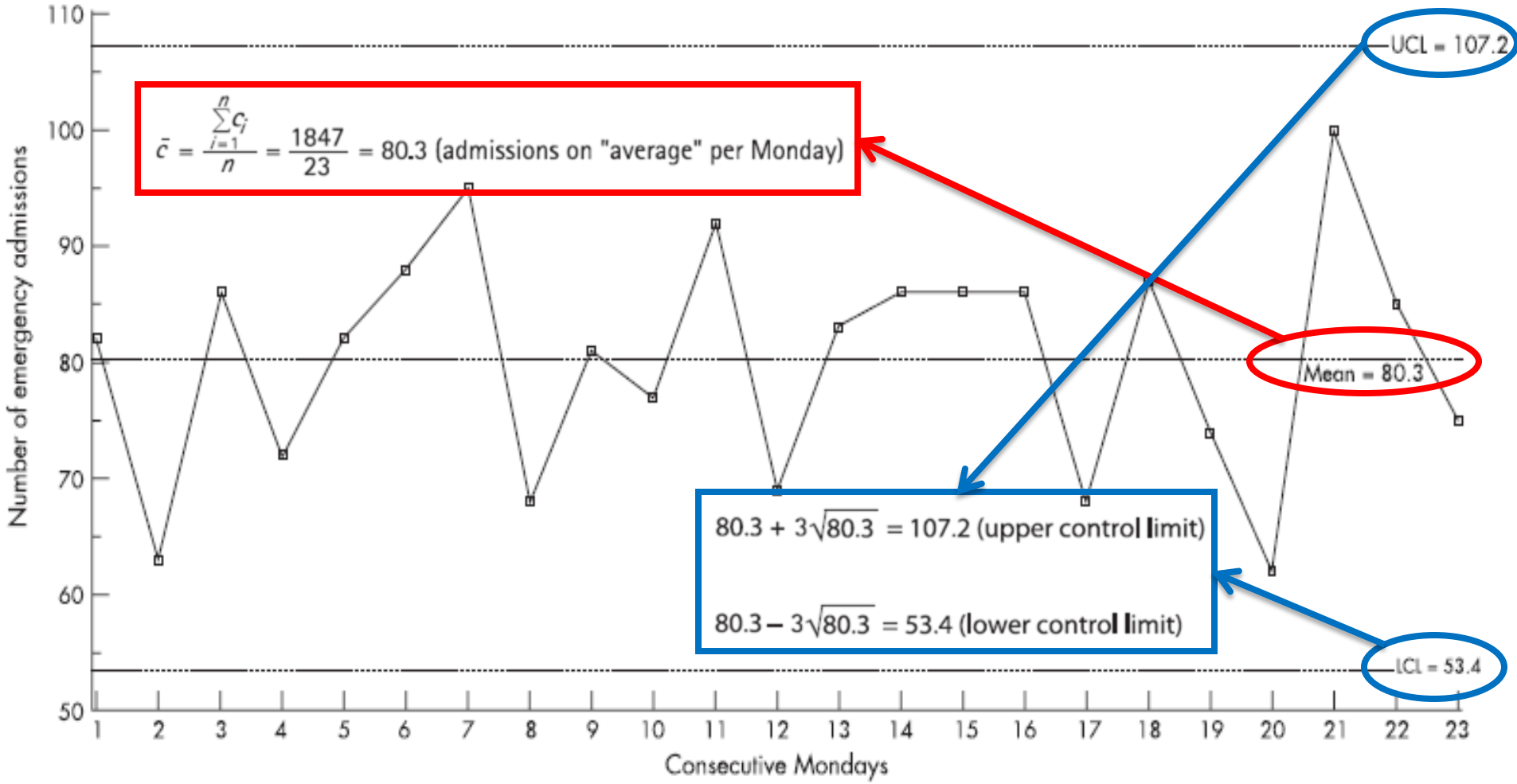
The c-chart

- Example： the number of emergency admissions over 23 consecutive Mondays (1 December 2003 to 3 May 2004) to one large acute hospital in England (personal communication).

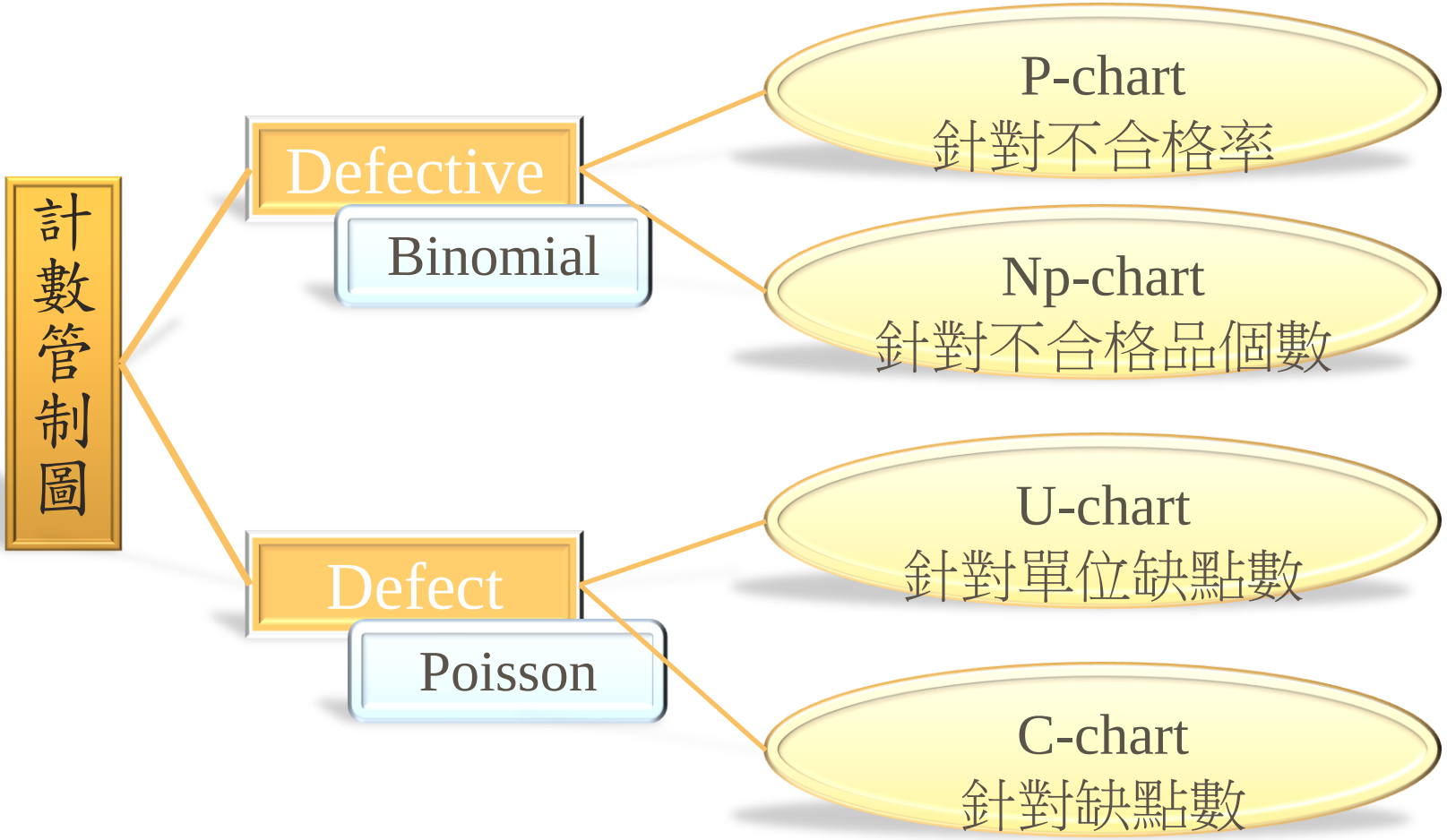
Monday number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Number of emergency admissions (c)	82	63	86	72	82	88	95	68	81	77	92	69	83	86	86	86	68	87	74	62	100	85

- 區分u-chart 和c-chart之差異:
  - 該事件有較低的頻率
  - 固定樣本大小

The c-chart


$\bar{c} = \frac{\sum_{i=1}^{n} c_i}{n} = \frac{1847}{23} = 80.3$ (admissions on "average" per Monday)
UCL = 107.2
Mean = 80.3
LCL = 53.4
$80.3 + 3\sqrt{80.3} = 107.2$ (upper control limit)
$80.3 - 3\sqrt{80.3} = 53.4$ (lower control limit)
Number of emergency admissions
Consecutive Mondays
110
100
90
80
70
60
50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

計數管制圖


計數管制圖
Defective
Binomial
P-chart
針對不合格率
Np-chart
針對不合格品個數
Defect
Poisson
U-chart
針對單位缺點數
C-chart
針對缺點數

Choice of Three-Sigma limits

Shewhart 1980

- 根據經驗和實務，穩定的製程中產生的變化在一定範圍內，在經濟控制的變化下，這些限制可以有效地定為three-sigma

Nelson 1999

- 凡是在控制限制定於一個有限正數，距離中線的風險錯誤。

Type I: to treat an outcome resulting from a common cause as if it were a special cause;
Type II: to treat an outcome resulting from a special cause as if it were a common cause.

探討

- 針對本論文，利用個案逐步解釋管制圖使用方式，更詳細介紹其過程。
- 但由於探討四個管制圖，並未能針對個案作分析。更可延伸方向有:
  - 針對醫療服務的性能來簡單探討比較。
  - 一批重大手術後的併發症
  - 緊急入院人數