

# Healthcare Quality Control and Improvement using *Stata*

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# Study of Variation: Process Behavior / Control Charts

Control charts developed by *Dr Walter Shewhart* (1891-1967) in US industry 1924+, used in healthcare since at least 1940's

## Common-cause

**variation** = random variation present in stable (healthcare) processes

## Special-cause variation

= **unpredictable deviation** resulting from a cause that is not an intrinsic part of a process



# Process Behavior / Control Charts (growing) Range of Applications

Markovic G, Schult M-L, Bartfai A, Elg M (2017). **Statistical process control: a feasibility study of the application of time-series measurement in early neurorehabilitation after acquired brain injury.** Journal of Rehabilitation Medicine, 49, 128-135.

Polit DH, Chaboyer W (2012). **Statistical process control in nursing research.** Research in Nursing & Health. 35, 82-93.

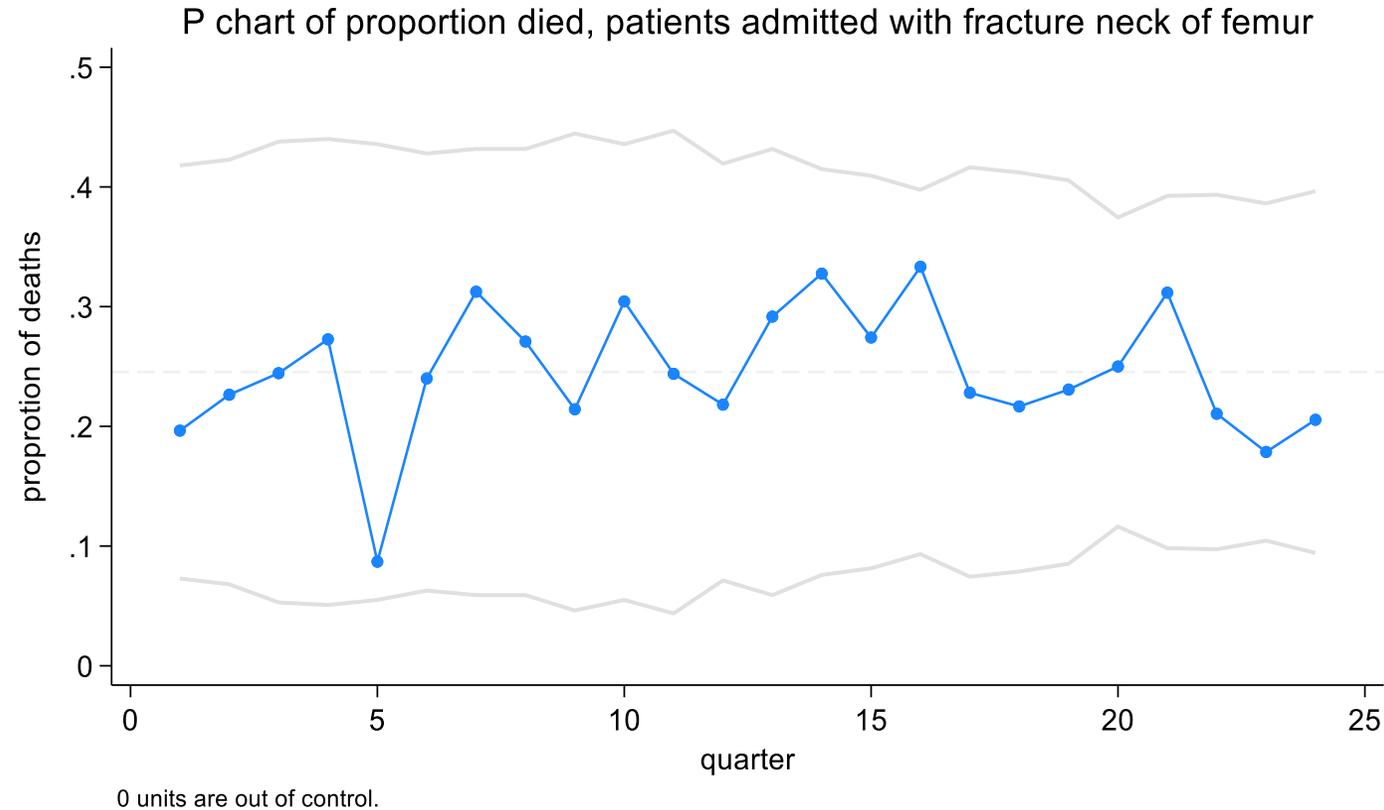
Tennant R, Mohammed MA, Coleman JJ, Martin V (2007). **Monitoring patients using control charts.** International Journal for Quality in Healthcare, 19, 187-194.

# P chart: Process Behavior / Control Chart for binary 'attribute' data

Scheffe H (1947). The relation of control charts to analysis of variance and chi-square tests. Journal of the American Statistical Association, 42, 425-431. 42, 634.

**Data from** Mohammed MA, Worthington P, Woodall WH (2008) Plotting basic control charts: tutorial notes for healthcare practitioners. Quality and Safety in Healthcare, 17, 137-145.

# Stata qc pchart pchart deaths quarter n\_admissions



Upper and lower **3 SD (99.8%)** control limits allow for **different sized denominators** (number of admissions per quarter)

Data from Mohammed, et al (2008)

# Comparing Hospitals / Wards / Groups

UK Hospital	A	B	C	D	E	Total
Died	250	276	198	149	143	1016
Admissions	521	746	520	551	386	2724
Mortality %	48.0	37.0	38.1	27.0	37.0	37.3

**5 anonymous UK hospitals, 1995-1997, mortality 6-month post diagnosis of acute stroke following index admission**

**Data from Mohammed MA & Holder R (2012) Introducing analysis of means to medical statistics. BMJ Quality & Safety, 17, 137-145.**

# Comparing Hospitals / Wards / Groups

Could compare pairs etc of hospitals using multiple comparisons, e.g. Bonferroni and Scheffe using **contrast** in Stata

Quality control / improvement in healthcare often uses graphic techniques such as funnel plots, comparing hospitals etc to overall hospital mean / proportion, similar to a control chart, but using **groups rather than timepoints**

This has (hopefully) replaced simple ranking of hospitals 'best' to worst', known as **League Tables**

# Comparing Hospitals / Wards / Groups

## 1/ Funnel Plots & (ANOM Analysis of Means)

Herdan G (1949) Control charts for the standard mortality ratio. British Journal of Social Medicine, 3, 69-76.

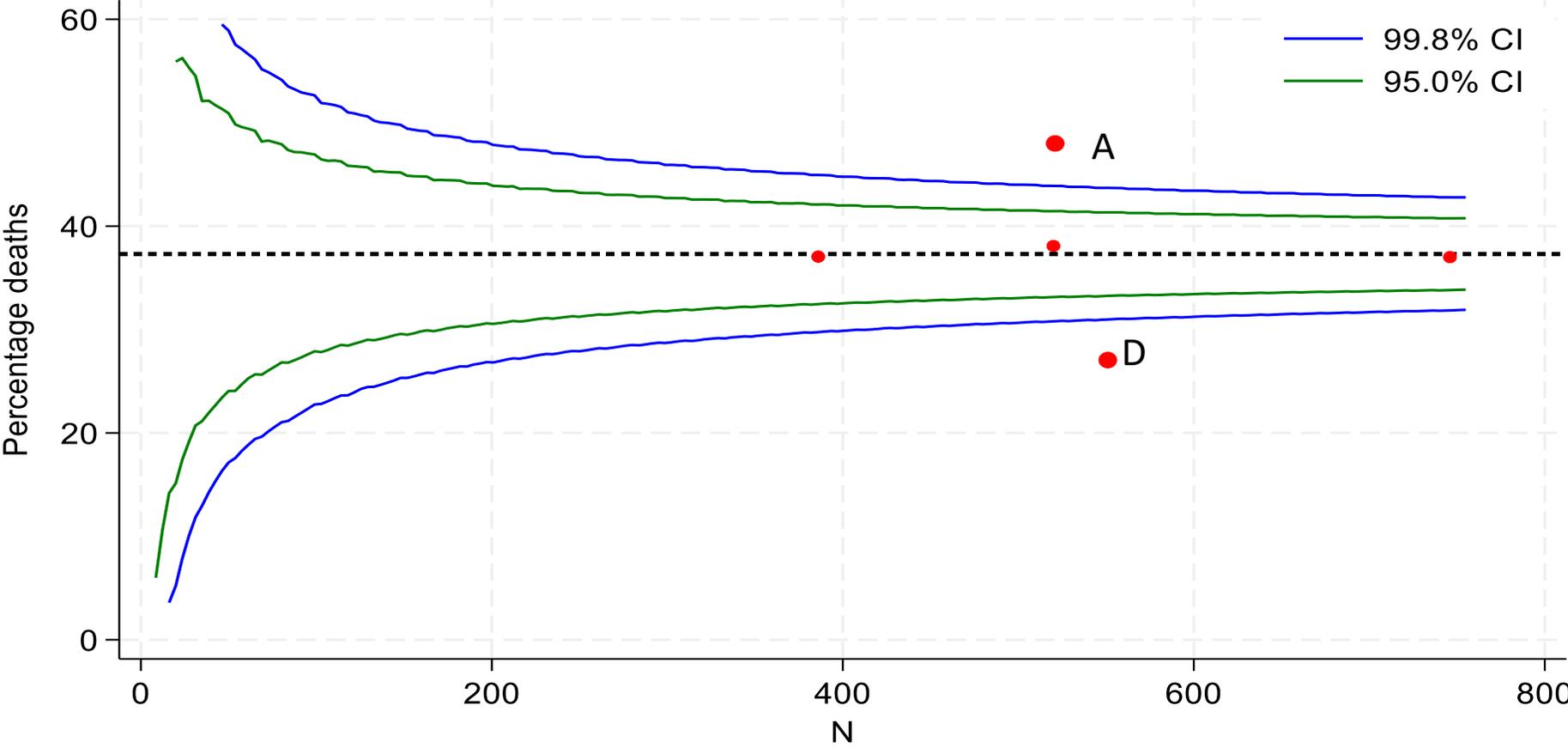
Spiegelhalter DJ (2005) Funnel plots for comparing institutional performance. Statistics in Medicine, 24, 1185-1202.

**Linden A & Spiegelhalter, DJ (2024). FUNNELINST: Stata module for generating a funnel plot to compare institutional performance.  
<https://ideas.repec.org/c/boc/bocode/s459283.html>**

ssc install funnelinst

funnelinst prop deaths admissions

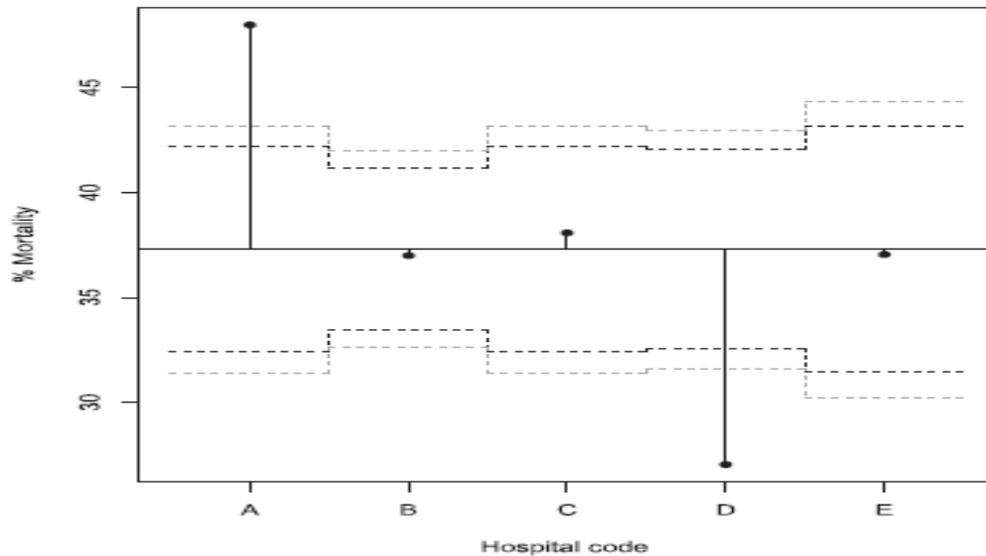
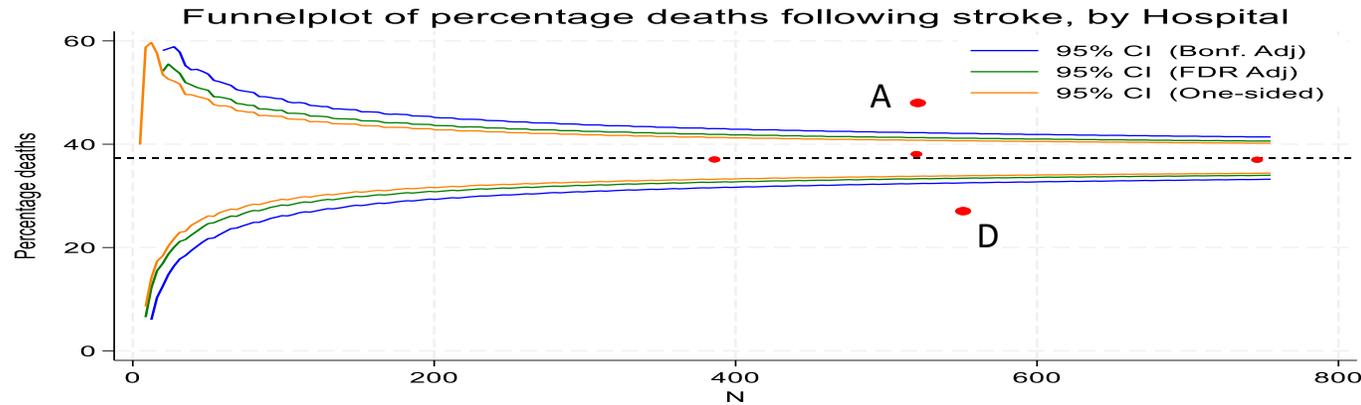
Funnelplot of percentage deaths following stroke, by Hospital



Data from Mohammed & Holder (2012)

ssc install funnelinst

funnelinst prop deaths admissions, madjust



## ANOM Analysis of Means Chart

Figure 2, Mohammed & Holder (2012)

Ott ER (1967) **Analysis of means – a graphical procedure**. Industrial Quality Control. 24, 101-109.

Rao CV (2005). **Analysis of means – a review**. Journal of Quality Technology, 37, 308-315.

# Comparing Hospitals / Wards / Groups

2/ compare / merge groups with each other:

**CHAID (Chi-square Automatic Interaction Detection)**

Biggs D, de Ville B, Suen E (1991). **A method of choosing multiway partitions for classification and decision trees.** Journal of Applied Statistics, 18, 49-62.

Kass GV (1980). **An exploratory technique for investigating large quantities of categorical data.** Applied Statistics, 29, 119-127.

McKenzie DP, Low LH (1992). **The construction of computerized classification systems using machine learning algorithms: an overview.** Computers in Human Behavior, 8, 155-167.

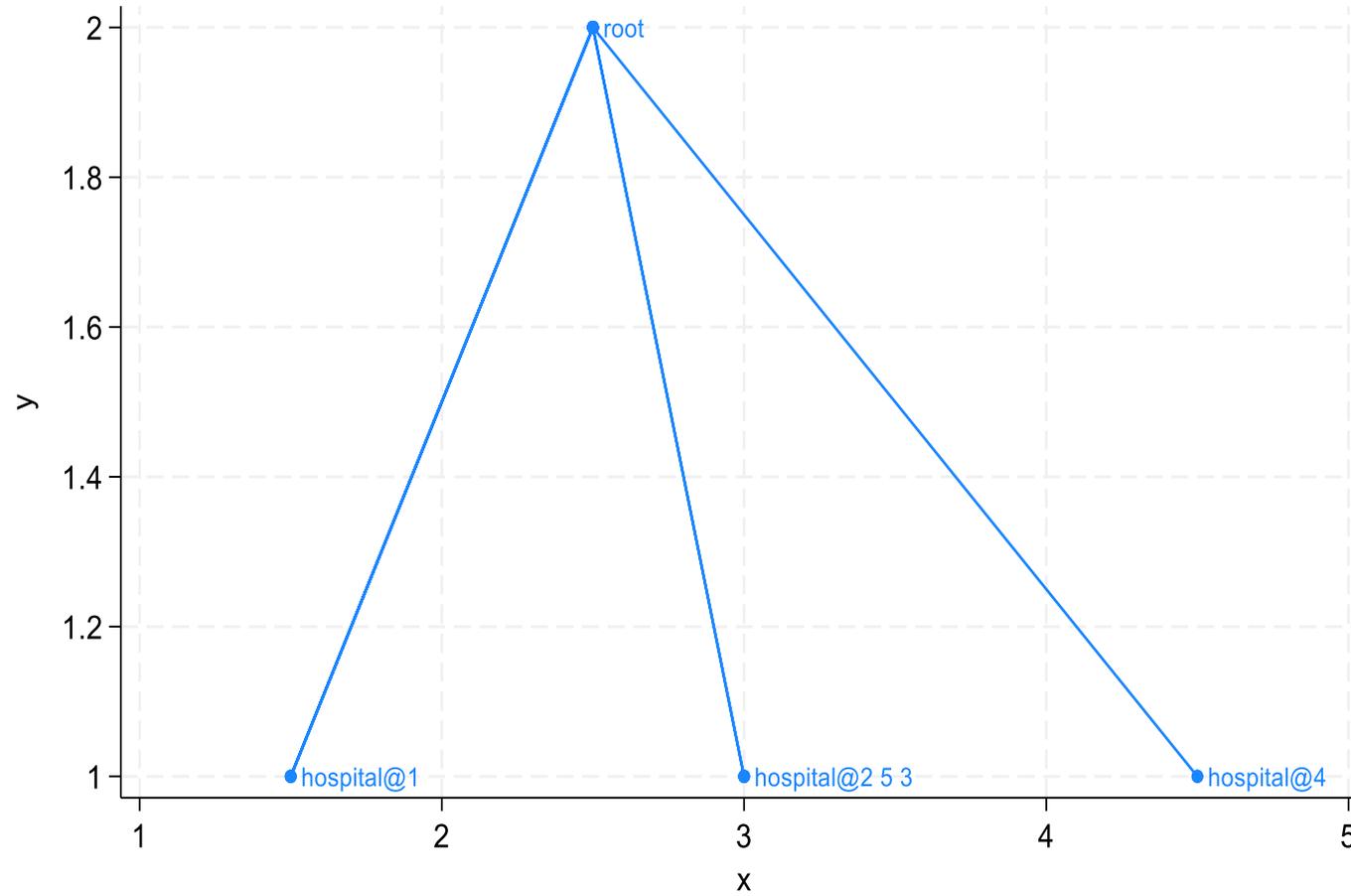
**Luchman JN (2013). **CHAID: Stata module to conduct chi-square automated interaction detection.** <https://ideas.repec.org/c/boc/bocode/s457752.html>**

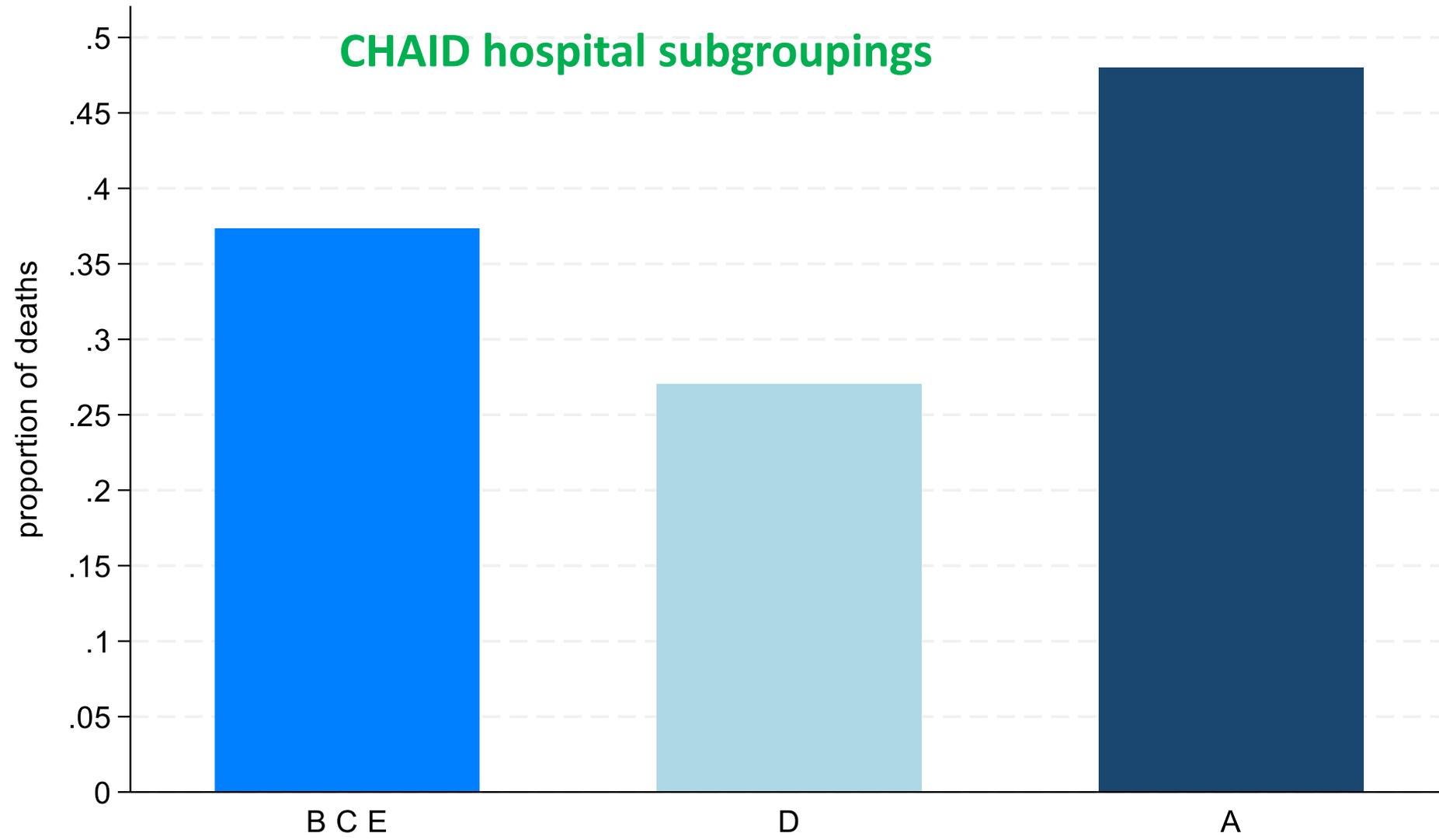
## Hospitals sorted by Mortality %

UK Hospital	A	C	B	E	D
Died	250	198	276	143	149
Admissions	521	529	746	386	551
Mortality %	48.0	38.2	37.0	37.0	27.0

ssc install chaid

chaid outcome [fw=freq],unordered(hospital)





# Pareto Charts Revisited

Juran JM (1962) Quality Control Handbook. 2<sup>nd</sup> ed. McGraw-Hill, New York.

Juran JM (1974). The Non-Pareto Principle; Mea Culpa. <https://www.juran.com/wp-content/uploads/2021/03/The-Non-Pareto-Principle-1974.pdf>

**Pareto charts: Joseph Juran (1904-2008), named after Vilfredo Pareto (1848-1923)  
Juran applied Pareto's concepts to quality control and coined the phrase "The vital few and the trivial many",  
(later the "useful many")**

**Original Pareto chart (Juran, 1962) used bar charts**

Figure 1B shows a Pareto analysis by type of defect.

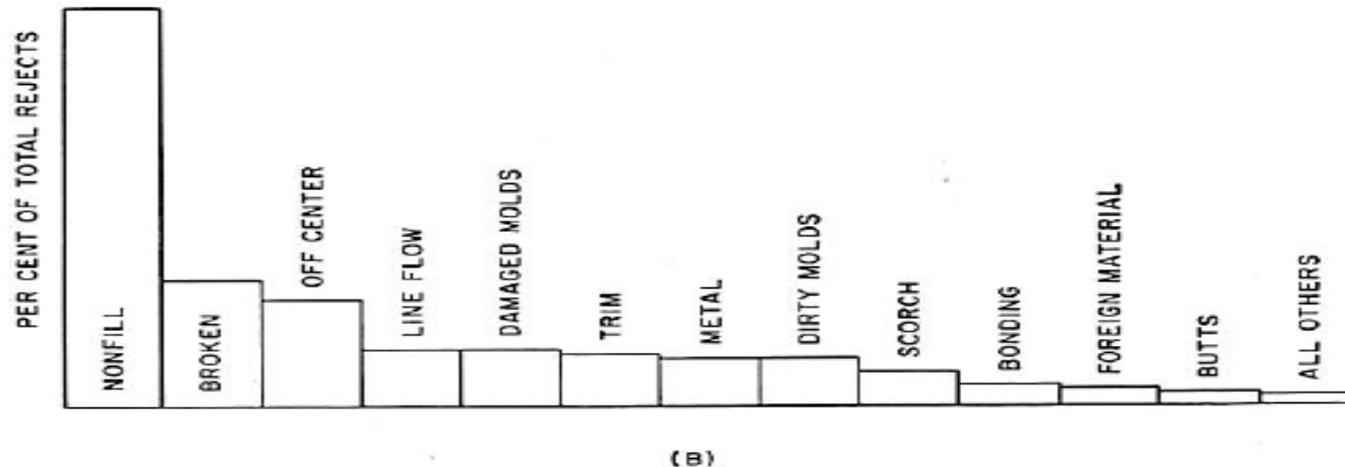


FIG. 1B. Pareto diagram of rubber molding rejects.

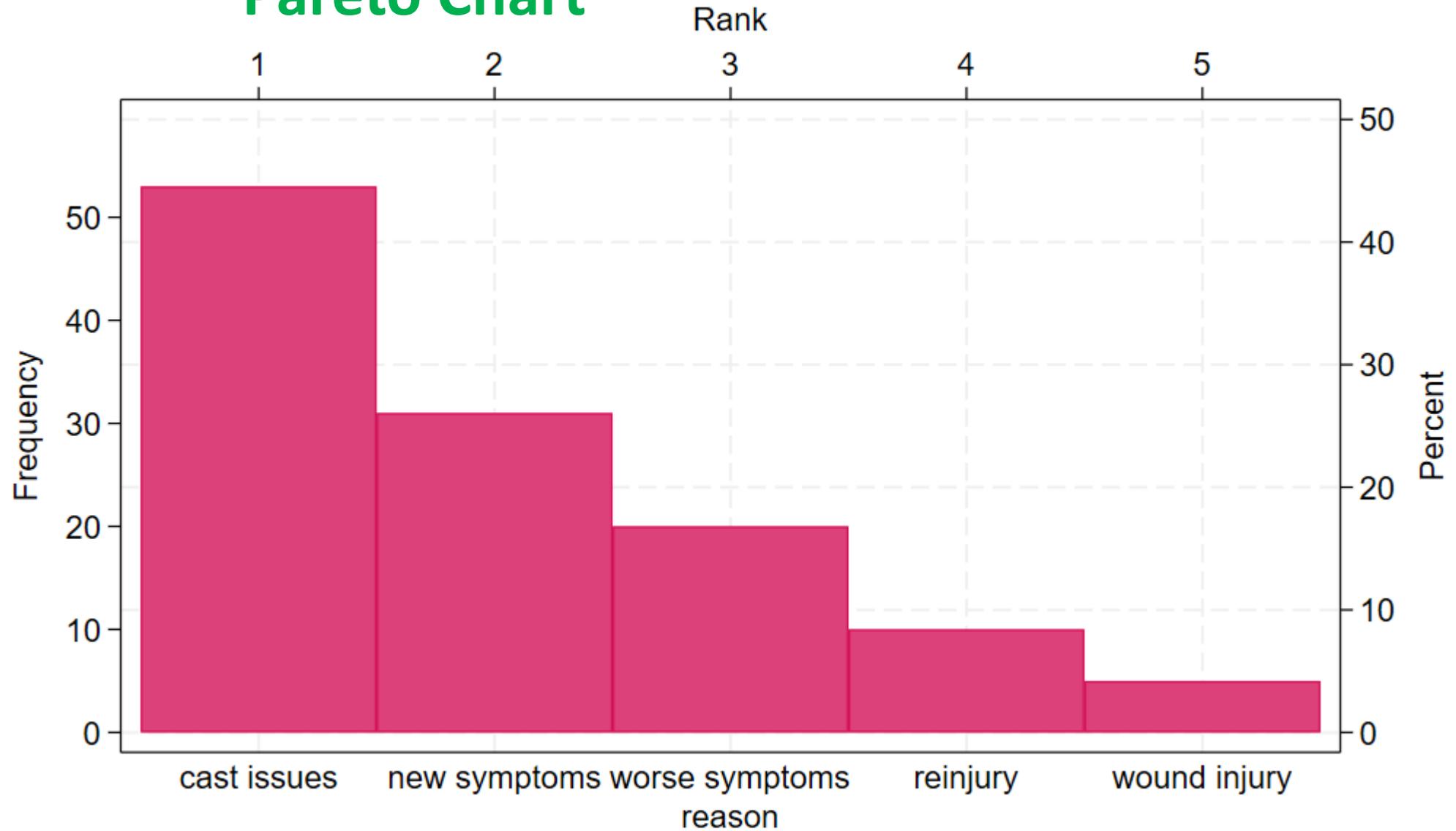
Juran (1962), 11-5

Wilkinson L (2006). Revising the Pareto chart. The American Statistician, 60, 332-334.

Liau K-H, Aung K-T, Chua N, Ho C-K, Chan C-Y, Kow A, Earnest A, Chia S-J (2010). Outcome of a strategy to reduce surgical site infection in a Tertiary-Care Hospital. Surgical Infections, 11, 151-159.

**Cox NJ (2006). PDPLOT: Stata module to produce Pareto dot plot.**  
**<https://ideas.repec.org/c/boc/bocode/s456790.html>**

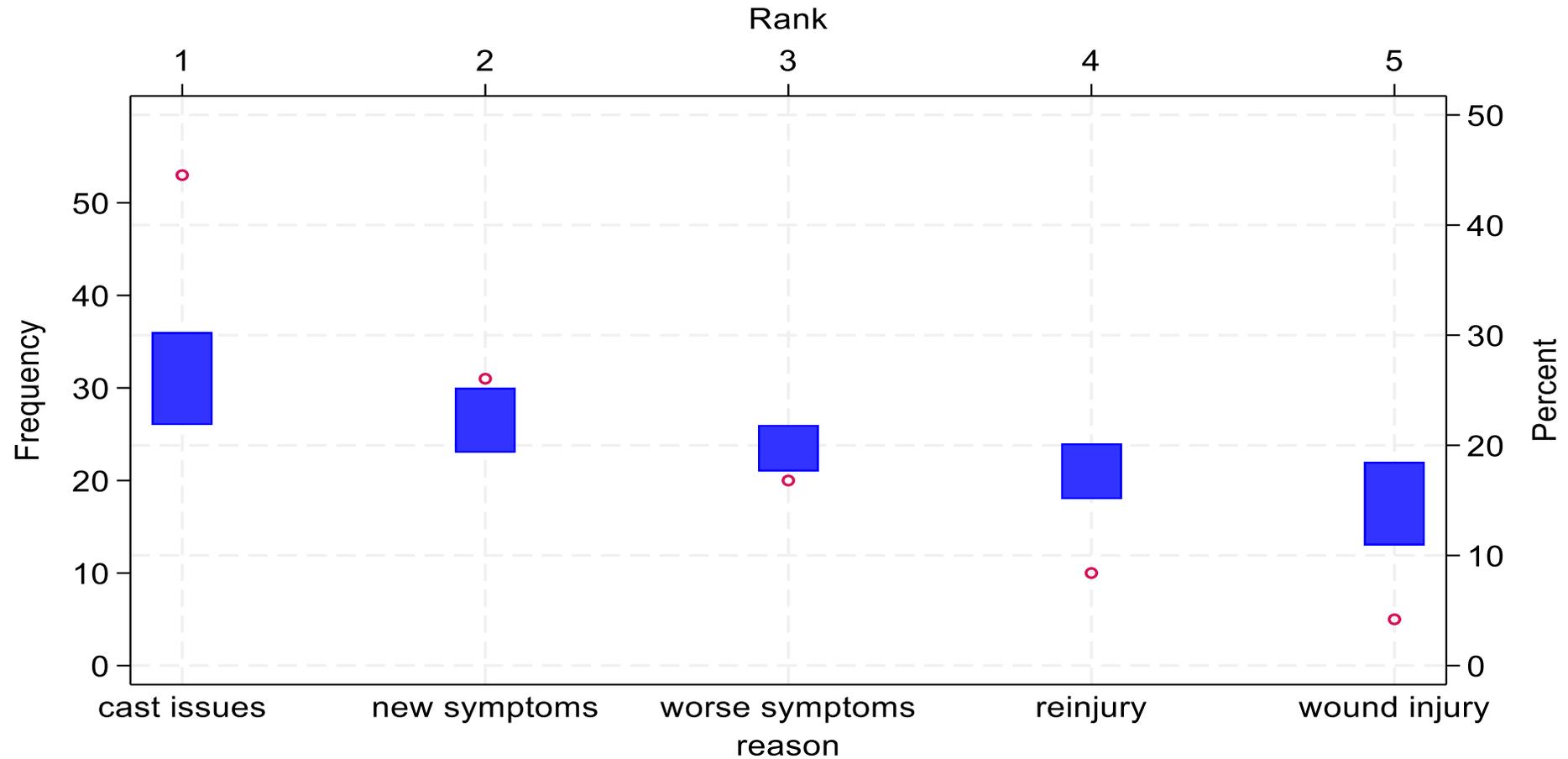
# Pareto Chart



Data from Little KJ, Trehan S, Cornwall R, et al (2018). Decreasing unexpected returns to orthopedic hand clinics: improving efficiency of health care delivery. Pediatric Quality & Safety, 3, e107.

ssc install pdplot

pdplot reason [fw=freq],aiopts(barwid(0.2) bcolor(blue))



95% acceptance intervals

# Looking for subtle Changes: CUSUM Cumulative Sum Charts: estat sbcusum

Page ES (1954) Continuous inspection schemes. Biometrika, 41, 100-115.

Walker HGM, McKenzie DP, Brooks KJ (2022). Competency assessment in focused cardiac ultrasound: can the use of sequential testing help tailor training requirements. Critical Care Exploration, 27, e0709.

Data from Holtzman WH (1963) Statistical methods for the study of change in the single case. In CW Harris (ed). Problems in measuring change. (pp 199-211). University of Wisconsin Press, Madison, Wisconsin.

***Person with schizophrenia, measured on perceptual speed, administered chlorpromazine after measurement 60 of 120 measurements***

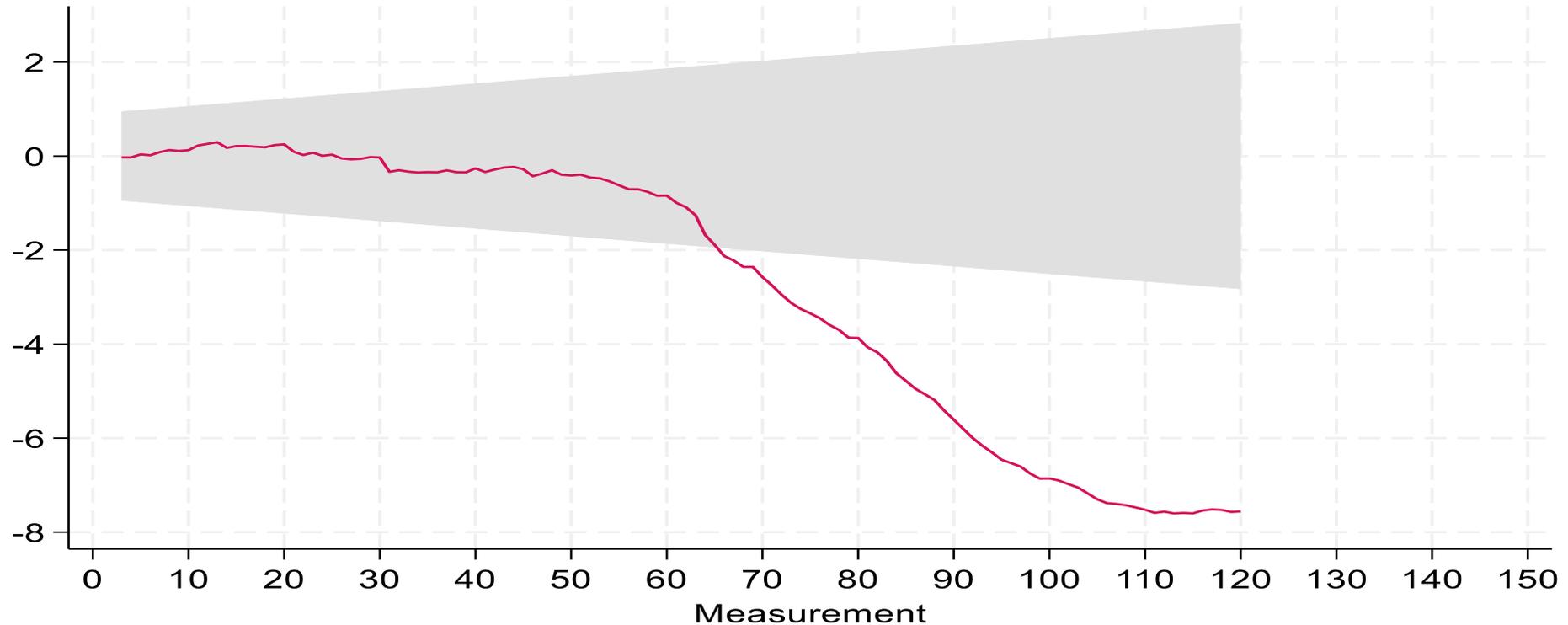
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Stata estat sbcusum
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tsset timepoint
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regress percep_speed timepoint
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estat sbcusum
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Recursive cusum plot of Perceptual Speed  
with 95% confidence bands around the null



Data from Holtzman (1963)

# *Stata has many useful routines for Quality Improvement etc*

*although Stata gc could usefully be extended (e.g. XmR charts?!)*



*(Using  
statistical  
routines  
outside of  
Stata.....)*

# Thank You!

**David & Natalie White, Survey Design and Analysis Services**

**Organizers and the Scientific Committee (esp Prof Arul Earnest)**

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**Epworth HealthCare**

**Monash University**

*MCRI (learnt Stata 199?, Dr Malcolm Rosier, Prof John Carlin, Prof George Patton)*