# 🛛 CUSUM Analysis

## Definition

**CUSUM (Cumulative Sum Control Chart) analysis** is a statistical technique used to monitor change detection over time. In medicine, it's widely applied to analyze **learning curves**—especially in surgical procedures—to detect improvement or deterioration in performance.

Cumulative sum (CUSUM) of deviations from a target performance level. Tracks case-by-case trends and identifies when competence is achieved or errors increase.

It plots the cumulative sum of deviations from a predefined target or acceptable outcome rate, providing a **visual and quantitative assessment** of proficiency acquisition.

# In Surgical Training

CUSUM helps evaluate **how many procedures a surgeon needs** to achieve competency in a new technique, such as ube, laparoscopy, or microsurgery.

#### Key Uses:

- Detect performance trends over time
- Identify the "turning point" where the surgeon achieves acceptable performance
- Differentiate between competence, proficiency, and mastery

### **How It Works**

Let:

- Xi = outcome of case \*i\* (success = 0, failure = 1)
- **p**<sub>0</sub> = acceptable failure rate
- **S**<sub>0</sub> = 0 (initial sum)
- Si = Si<sub>-1</sub> + (Xi p<sub>0</sub>)

Then:

- A steep upward trend suggests consistent failures (worsening performance)
- A downward slope indicates **learning and improvement**
- A flat line reflects **stable**, **competent performance**

## Example in UBE

In a narrative\_review on ube training, CUSUM analysis was used to assess:

- Early technical errors (e.g., incomplete decompression, nerve root irritation)
- Operative time benchmarks
- Conversion to open surgery

This method revealed that **significant proficiency** in UBE lumbar decompression was typically achieved after **20-30 cases**, depending on prior endoscopic experience <sup>1)</sup>.

### Advantages

- Objective tool for tracking learning curves
- Provides early warning for declining performance
- Can be adapted to binary (success/failure) or continuous variables (e.g., operative time)

#### **▲** Limitations

- Requires consistent, well-defined outcome measures
- Sensitive to data quality and completeness
- May need combination with other metrics (e.g., risk-adjusted CUSUM, EWMA)

# CUSUM Analysis for Lumbar Puncture

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## Objective

To evaluate the learning curve of medical trainees performing **[lumbar\_puncture]**, using **[cusum\_analysis]** to track the rate of successful procedures and determine the point at which competency is achieved.

#### Method

**Target failure rate (po):** 20% **Success =** CSF obtained without requiring supervisor takeover **Failure =** CSF not obtained, traumatic puncture, or supervisor takeover

Let:

• Xi = 0 for success, 1 for failure

• Si = cumulative sum of (Xi -  $p_0$ )

Initial value  $S_0 = 0$ 

### **Example Case Series (First 20 LPs)**

Case #	Outcome	Xi	Si = Si - 1 + (Xi - 0.2)
1	Success	0	0 - 0.2 = <b>-0.2</b>
2	Success	0	-0.2 - 0.2 = <b>-0.4</b>
3	Failure	1	-0.4 + 0.8 = <b>0.4</b>
4	Success	0	0.4 - 0.2 = <b>0.2</b>
5	Success	0	0.2 - 0.2 = <b>0.0</b>
6	Success	0	0.0 - 0.2 = <b>-0.2</b>
7	Success	0	-0.2 - 0.2 = <b>-0.4</b>
8	Failure	1	-0.4 + 0.8 = <b>0.4</b>
9	Success	0	0.4 - 0.2 = <b>0.2</b>
10	Success	0	0.2 - 0.2 = <b>0.0</b>
11	Success	0	0.0 - 0.2 = <b>-0.2</b>
12	Success	0	-0.2 - 0.2 = <b>-0.4</b>
13	Success	0	-0.4 - 0.2 = <b>-0.6</b>
14	Success	0	-0.6 - 0.2 = <b>-0.8</b>
15	Failure	1	-0.8 + 0.8 = <b>0.0</b>
16	Success	0	0.0 - 0.2 = <b>-0.2</b>
17	Success	0	-0.2 - 0.2 = <b>-0.4</b>
18	Success	0	-0.4 - 0.2 = <b>-0.6</b>
19	Success	0	-0.6 - 0.2 = <b>-0.8</b>
20	Success	0	-0.8 - 0.2 = <b>-1.0</b>

## Interpretation

The **CUSUM chart** would show an **initial learning phase** with small performance fluctuations. Around case **15-20**, the steady negative slope indicates consistent success below the target failure rate, suggesting **competency is achieved** after ~18-20 procedures.

### 🛛 Takeaways

- CUSUM is a powerful tool to track [learning\_curve] in procedural skills.
- In this example, the trainee reached proficiency in LP after  $\sim$ 20 cases.
- Regular monitoring helps detect early need for intervention or additional training.

#### **CUSUM Analysis for Intracranial Pressure Monitor Placement**

#### CUSUM Analysis for Intracranial Pressure Monitor Placement

#### 1)

Espinoza XAS, Pérez EG, Choi DJ. The unilateral biportal endoscopy journey: proposing a 10-tier difficulty progression framework for unilateral biportal endoscopy. Asian Spine J. 2025 Apr 7. doi: 10.31616/asj.2025.0064. Epub ahead of print. PMID: 40195633.

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