**Introducing the I′-chart: an improved I-chart**

**Introduction**

Statistical Process Control (SPC) is widely used in healthcare to monitor and improve the quality and safety of care delivery processes [ref]. At its core, SPC methodology distinguishes between two types of variation: common cause variation, which reflects inherent fluctuations within a stable process and special cause variation, which signals a change in the underlying process due to an assignable cause. SPC charts help users visualise the behaviour of data from a process and identify signals of special cause variation using statistically defined control limits.

There are scores of SPC charts and choosing the appropriate chart can be less than straightforward, especially in healthcare, where data structures are often complex and varied. Measurement data, counts, proportions, and rates with changing denominators are all common—each requiring a different type of control chart. Compounding this challenge is the fact that some practitioners lack formal statistical training, and software defaults often promote the use of a single chart type, typically the Individuals (I-)chart, regardless of whether it is the most appropriate. These issues can lead to the misapplication of SPC charts, generating misleading signals and undermining improvement efforts.

Moreover, among SPC charts, the Individuals (I)-chart is especially popular for its simplicity and flexibility. It is well suited to settings where data are collected as single observations over time—for example, daily blood pressure readings, weekly number of x-rays, or individual lab test turnaround times. Unlike other SPC charts, the I-chart estimates process variation directly from the moving range between successive data points [ref] because the data are individual data points with no subgroups (subgroup size=1). So the I-chart operates under a key assumption: that each data point reflects the same underlying area of opportunity—for example, comparable patient volumes, observation periods, or sample sizes. In many healthcare contexts, this assumption does not hold. For instance, the percentage of patients with post-surgical complications depends on the number of patients who underwent surgery (the denominator), which varies over time. When such variation in denominators or subgroup sizes exists, the use of the I-chart becomes problematic, because the I-chart assumes a constant denominator or area of opportunity. This assumption can lead to misleading control limits, and this is why the use of the I-chart for such data remains controversial.

To address this limitation, we introduce the I-prime (I′-chart), a modified version of the I-chart that was recently developed by Taylor [ref] that accommodates varying denominators or subgroup sizes. In this paper, we introduce the I′-chart, outline its theoretical foundation and evaluate its performance using a range of healthcare data sets. Our paper is guided by the following practical questions:

1. How does the I′-chart accommodate varying sample sizes or denominators and how does it compare with the I-chart?
2. How does the I′-chart compare with four widely used SPC charts (Xbar, P, C, and U)?

**Methods (to follow)**

**Results –**

**Discussion**

We introduced and evaluated the performance and applicability of the I′-chart, a modified form of the traditional Individuals I-chart, designed to account for variation in subgroup sizes. We have three key findings. (1) We found that the I′-chart produces results that are an exact match to the original I-chart when applied to individual measurement data where there are no denominators (subgroup size=1). This validates the I′-chart as a generalization rather than a replacement, ensuring continuity for users familiar with the original method. (2) We found that the I′-chart closely approximates the behaviour of Laney’s prime charts (P′-chart and U′-charts), because they too consider within and between subgroup variation, and are recommended for analysing proportions and rates, especially when denominators are large. (3) Additionally, while not an exact substitute, the I′-chart shows reasonable alignment with other popular SPC charts (X̄-, C-, U-, and P-charts). [is this because these traditional charts do not accommodate, both, within and between subgroup variation and the prime charts (Laneys and Taylors) do, hence the extent to divergence between the two approaches depends on the magnitude of the within/between subgroup variation.]

A distinctive feature of the I′-chart is that it produces control limits that are “wavy” or undulating when denominators change over time. This visual representation offers added insight, making variability in data precision explicit and encouraging more insightful interpretation. In addition, for measurement and count data with varying denominators, the I′-chart adjusts the center line (?weighted average) and control limits in proportion to subgroup size. This makes it more sensitive and appropriate in real-world healthcare settings where case volume, exposure time, or other denominators often vary over time. By accounting for these differences, the I′-chart reduces the risk of false-signals.

A key strength of the I′-chart is that it maintains the simplicity of the I-chart while offering a more context-sensitive representation of variation. One potential barrier to the adoption of the I′- chart is its more complex formulae compared to the standard I-chart. Calculating variable control limits that adjust for changing denominators involves additional statistical steps, which may be a barrier to practitioners accustomed to simpler SPC methods. However, this complexity is readily overcome with modern software tools, which can automate these calculations and present the results in user-friendly formats. As with other advanced analytic techniques in healthcare, once embedded in software, the additional complexity becomes largely invisible to end users—allowing them to benefit from more accurate and context-sensitive charts without increasing the technical burden. We recommend that SPC software incorporate the I′-chart but also make it easy for users to compare traditional SPC charts (eg I-chart, p-chart, etc) alongside the I′-chart (and other prime charts), because this side-by-side comparison of data using different SPC charts itself can also be insightful [ref].

The I’-chart has superior design properties to the traditional I-chart and so merits broader use and evaluation. Our findings demonstrate that the I′-chart retains the simplicity and intuitive appeal of the I-chart whilst accommodating variation in denominators, making it suitable for both measurement and count data. We are keen to learn how others in the field perceive its value and whether it enhances their ability to monitor and improve processes using real-world healthcare data.