[2–4] quoted in his letter were unknown to us.

We believe that the topic is so important that it deserves a wider base than that published in the quoted references.

Regarding the hair pigment trichosiderin, Flesch and Rothman [2] found this substance only in red-haired subjects. The structure as well as the biological function of trichosiderin have not yet been elucidated. In our study we examined no red-haired individuals. But if one considers the world population at risk of iron deficiency as a whole, the proportion of red-haired individuals is small. Despite some differences in hair iron concentrations that could be related to hair color [5], it is speculation to regard trichosiderin as a potential hindrance in the clinical use of hair iron concentration. Moreover, Creason et al. [5] found that vanadium and iron in hair were significantly correlated. This finding is interesting because vanadium is bound, as is iron, to transferrin in blood.

The main problem in measuring trace elements in hair is the absence of a scientifically based reference procedure, and hair iron values differ considerably among laboratories. Before examining hair iron in patients and in healthy subjects, the iron status of all subjects should first be clearly described and staged by the currently established tests. The quality management of the data is also very important. Unfortunately the authors quoted by Beutler have used only serum iron for the evaluation of iron status. Therefore they could neither clearly characterize the groups nor distinguish between iron-deficiency anemia and the anemia related to infections, inflammation, or malignancy. This and the analytical problems may partially explain the inconsistent trends observed [3, 4].

The low ferritin concentrations found in our patients clearly indicate that the organism was not basically influenced by the inflammation. Thus our results allow no general statement for patients with chronic bowel diseases or patients with other inflammatory diseases.

Extended studies that include different groups of patients as well as healthy individuals must be performed before we can obtain deeper insight into the metabolic pathway of hair iron. The iron status must be evaluated by using transferrin receptor and zinc protoporphyrin in addition to the conventional tests of iron status.

Until solid experimental data are available, it is premature to reach final conclusions on the clinical value of hair iron concentration.

**References**


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The author of the letter responds:

To the Editor:

It is not uncommon for investigators to incline toward the view that any studies performed >10 years ago must be flawed because of the primitive nature of science before current technology was available. However, hematologists were able to diagnose iron deficiency quite accurately even 40 years ago [1] without the advantage of serum ferritin concentrations. Hematologists such as Green and Duffield, and Lovric and Pepper were well qualified to make the distinction between the anemia of iron deficiency and that of inflammation, and I do not believe that their findings should be dismissed lightly merely because they were performed many years ago.

**Equivalence of Critical Error Calculations and Process Capability Index Cpk**

**To the Editor:**

The concept of process capability has been used by the manufacturing industry to quantify the relation between product specifications and the measured process performance [1]. Various ratios and indices have been developed to describe this relation. We have previously reported the application of the simplest of these, C_p (the capability index or capability ratio), to the selection of quality-control (QC) algorithms appropriate to the specification limits and analytical imprecision [2]. C_p is defined as (USL–LSL)/6σ, where USL and LSL are the upper and lower specification limits of an analytical process, and σ is the standard deviation of the process.

In contrast to the approach taken by us, the use of medically important critical systematic error (ΔSE_c) and critical random error (ΔRE_c) calculations for the selection of QC algorithms has been promulgated [3–5]. Westgard and Burnett [6] have also described the relation between C_p and ΔSE_c and have shown that, assuming zero bias, C_p can be directly related to ΔSE_c by equation:

$$ΔSE_c = 3C_p - z$$  \( (1) \)

where z is a factor for a one-tailed test of significance (usually set at 1.65 for 95% confidence, assuming a gaussian distribution).
A limitation of the use of $C_p$ is that this particular capability index does not consider any bias present within the analytical process. $C_{pk}$ is a related capability index used by the manufacturing industry that considers bias as well as imprecision [1] and is defined as:

$$C_{pk} = \min \left[ \frac{\mu - LSL}{3\sigma}, \frac{USL - \mu}{3\sigma} \right]$$

where USL, LSL, and $\sigma$ are as for $C_p$ and $\mu$ is the mean of the process.

We have now derived the mathematical relation between the process capability index, $C_{pk}$, and medically important critical errors, $\Delta SE_c$ and $\Delta RE_C$, for cases of nonzero bias.

If the bias is nonzero and the specification limits are symmetrical about the “true value” ($\bar{X}_0$), then:

$$USL = \bar{X}_0 + TE_a$$

and

$$LSL = \bar{X}_0 - TE_a$$

Therefore, $C_{pk} =$

$$\min \left[ \frac{TE_a + \mu - \bar{X}_0}{3\sigma}, \frac{TE_a + \bar{X}_0 - \mu}{3\sigma} \right]$$

or

$$C_{pk} = \frac{\left| TE_a - (\mu - \bar{X}_0) \right|}{3\sigma} = \frac{TE_a - \text{bias}}{3\sigma}$$

From ref. 6:

$$\Delta SE_c = \frac{TE_a - \text{bias}}{\sigma} - z$$

By substitution:

$$\Delta SE_c = 3C_{pk} - z \quad (2)$$

Similarly:

$$\Delta RE_C = 3C_{pk}/z_2 \quad (3)$$

where $z$ is as defined above, and $z_2$ is a factor for a two-tailed test of significance (usually set at 1.96 for 95% confidence, assuming a gaussian distribution). The previously derived relation [6] between $\Delta SE_c$ and $C_p$ shown in Eq. 1 can now be seen to be a limiting value of Eq. 2 for the special case of zero bias.

We have found that implementation of a QC strategy based on capability indices may be conceptually easier to understand than one based on $\Delta SE_c$ and $\Delta RE_C$ [2]. By rearranging Eqs. 2 and 3, we can derive:

$$C_{pk} = \frac{\Delta SE_c + z}{3} \quad (4)$$

and

$$C_{pk} = \frac{\Delta RE_C \times z_2}{3} \quad (5)$$

This form of the relation may facilitate the educational and training process for those laboratories that choose this perspective. Conversely, for those laboratories that have been using QC strategies based on process capabilities, a simple pathway is now offered to convert their strategies to the more widely adopted approach of using critical error parameters.

There exists ready availability of computational aids for the selection of QC algorithms based on critical errors, such as the “QC Validator” software program [7] and the use of QC selection grids [8]. As Eqs. 2 through 5 permit interconversion of $C_{pk}$ with $\Delta SE_c$ and $\Delta RE_C$, there appears to be no need to develop parallel sets of tools based on $C_{pk}$.

The demonstration of the mathematical equivalence of $\Delta SE_c$, $\Delta RE_C$, and $C_{pk}$ now permits a unification of those approaches based around process capability [2] and those around medically important critical errors [3–5]. Finally, the equivalence between approaches based on critical error and $C_p$ [6], and now also $C_{pk}$, means that there is available a common language between clinical chemistry and quality professionals in the manufacturing industry.

**References**


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