The science behind the quest to determine the age of bruises—a review of the English language literature

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Abstract Bruises are common injuries that can have medicolegal significance. There are those that maintain it is not possible to estimate the age of bruises. However, appreciation of the biological processes related to the resolution of a bruise suggests that these may provide information regarding the age of a bruise. Potential methods for determining the age of bruises—visual observation, colorimetry, spectrophotometry and histology—are reviewed. The observation of yellow (not orange or brown) indicates a bruise is not recent, but the abilities of visual observation are limited by the physiology of the human eye. Analysis of spectrophotometric data may provide more useful and objective information. Histological examination may be appropriate only in the postmortem situation. The lack of published information limits this as a tool for estimating the age of bruises. It is not known how the wide range of factors that can influence bruise formation and resolution could affect estimation of bruise age.

Keywords Bruise · Skin · Human · Time factors · Color perception · Colorimetry · Spectrophotometry · Histology · Pathology · Review · Forensic

The word bruise is derived from the old English word bry-san, which means to crush [1]. For a bruise to occur, three criteria have to be satisfied. First, the skin has to be stretched or crushed sufficiently to cause tearing of blood vessels within it or in the underlying fat, but without resulting in loss of integrity of the surface [2–4]. In order for this to occur, the skin must be deformed by a blunt instrument, otherwise the skin will be cut before vessels tear. If the elastic limit of the surface of the skin being deformed is exceeded, a laceration will form (the skin is split). Conversely, the degree of trauma may be minimal and not noticed if the vessels are fragile, for example in the elderly [5]. Second, after the vessels in the skin are damaged there has to be sufficient pressure of blood to cause escape of red blood cells from vessels into the tissue. Third, the escaped blood must be sufficiently near the surface of the skin to be visible. This will vary with the optical properties of the skin. A bruise inflicted during life might not be visible due to the opacity of skin [6–8], but it will be revealed postmortem by skin reflection [9, 10]. Bruises may not be inconsequential injuries as they can result in death if extensive [11, 12].

The early appearance of a bruise is dependent on two factors: escape of hemoglobin-containing erythrocytes from blood vessels into the tissue and the depth of the blood within the skin [13–15]. Over time, the appearance depends on diffusion of hemoglobin through the tissues and removal of hemoglobin by the inflammatory response [1].

Hemoglobin has the role of transporting oxygen from the lungs to the tissues of the body. It is composed of a porphyrin ring around an iron atom [16]. The spectrum of deoxyhemoglobin has a sharp peak at 430 nm and broad peak around 555 nm. It appears slightly darker than the bright red of oxyhemoglobin, which has peaks around 415 nm, 540 nm and 575 nm [17–19]. The presence of hemoglobin near the surface of the skin will appear red, but release of blood deeper into the tissue is said to appear blue, an effect that is attributed to Rayleigh scattering, absorption coefficients of skin and interpretation by the visual system [13, 15, 18, 20]. A similar effect is seen with melanin, which appears as a yellow pigment when superficial, but can appear blue when deep [20, 21].
The release of blood into the tissue will evoke an inflammatory reaction [22] and this response may be accentuated by tissue damage due to blunt trauma [23, 24]. Neutrophils are the first cells to arrive, but these probably cannot degrade hemoglobin [4, 25]. Macrophages can phagocytose erythrocytes [26] and they contain heme oxygenase that enables the first step of hemoglobin breakdown. Hemoglobin is split into biliverdin by heme oxygenase [27]. This reaction is energy-dependent, requires oxygen and results in the release of carbon monoxide and the iron atom. Biliverdin is a green pigment and it is rapidly changed to bilirubin, a yellow pigment, by the enzyme biliverdin reductase [28, 29]. It is likely that the free iron is locally bound to ferritin [27] and that hemosiderin is a polymer of ferritin [30, 31]. It also appears that bilirubin can accumulate to form local yellow crystals that have been referred to as hematoidin, [32] which may dissolve in tissue processing [33].

Heme oxygenase has been recognized as having a potential role in modulation of the inflammatory response [25]. Two isoforms have been characterized; inducible heme oxygenase -1 and constitutively expressed heme oxygenase -2, which is found in a wide range of tissues [27, 34]. The form within macrophages is heme oxygenase -1 and it is usually present at low levels [35]. Its levels rise following phagocytosis of erythrocytes [25, 26, 33] or exposure to hemoglobin [28] and it may be detected by immunohistochemistry as early as 3 h following the release of blood into the tissues in humans [36]. Heme oxygenase is also present in an inducible form in fibroblasts (present in the skin) [37], but the role of fibroblasts in clearing of hemoglobin in a bruise has not been established [37].

Thus, the initial appearance of a bruise is due to the ability to perceive blood that has been released within the skin (for these purposes, the earliest reaction to trauma—the wheal and flare response [38, 39]—will be ignored). A bruise may become established as early as 15–20 min after injury (in a porcine model, struck by a paintball) [40]. It is written that the early color depends on the depth of the blood within the skin [15, 18, 41]. Colors that may be reported as red, blue, purple, black or green are no guide to the age of a bruise [42]. It may be that some of these colors are perceived as a result of the effect of contrast on the human eye–brain visual system rather than due to their actual presence [18, 43]; this could occur because color is a perception, not a property of the skin [44]. Changes in the colors seen in a bruise will occur due to shifting of the position of blood relative to the skin surface [1] and may be augmented by the released hemoglobin changing from oxyhemoglobin to deoxyhemoglobin [45]. In addition, it has been recently suggested that production of carbon monoxide during the catabolism of hemoglobin [37] could allow the local formation of carboxyhemoglobin, which could make bruises appear a brighter red [46].

The production of bilirubin and hemosiderin at the site of a bruise requires time for macrophage recruitment, inducement of heme oxygenase and catabolism of hemoglobin [35]. The development of yellow color in bruises has been attributed to the local production of bilirubin [28, 47] which can be justified, as raised serum bilirubin levels correlate roughly with the yellowness of the skin in jaundiced neonates [48]. Observation of a bruise, either directly or from photographs, has been the traditional method by which the age of a bruise may be estimated. Many old forensic textbooks [49–54] and even more recent publications [55] include guides to determining the age of a bruise based on its color. However, consideration of the biological processes occurring in a bruise supports the conclusion that only the appearance of the color yellow would provide any information regarding the age of a bruise when using observation alone [42]. If a bruise is directly accessible it could be suggested that recording factors such as tenderness and swelling might assist with determining the age of the injury [56], but there is no evidence that this would be the case.

Thus, the perception of any color such as ‘blue’, ‘green’, ‘purple’, ‘black’, ‘orange’, ‘brown’ or ‘red’ indicates nothing about the age of a bruise. Statements such as ‘a bruise that is blue is recent’ cannot be substantiated—it could well equally be old. Similarly, ‘a fresh bruise will be red’ is not justifiable, as an old bruise may be red: [42, 57, 58] consider ‘senile purpura’, which tends to retain its red color. Some have stated that the presence of green color in a bruise reflects the presence of biliverdin; indeed, biliverdin may be present in some forms of jaundice, where it will impart a green tinge to the skin [59]. However, there is no evidence to support that biliverdin will accumulate in bruises in humans [60–62], but it may develop in some animals [60, 63, 64]. Mathematical modelling of the optical properties of deep blood indicates that it may appear as blue or turquoise color [18]. Green could be perceived from a mixture [65] of this with yellow from skin pigmentation (see below).

If yellow is seen in a bruise, then that bruise is not recent [66] (provided it has not been inflicted on the site of a pre-existing older injury that was already showing yellow color). There are a number of important points to this statement.

‘Yellow’ means bright yellow, not ‘orange or ‘brown’—to see an example of true yellow use any painting or image processing program with the color values red 240, green 240, blue 0. This author has seen the colors orange and brown in very early bruises, most notably in infants. However, orange and brown may be perceived due to the presence of methemoglobin. Methemoglobin has a brown color [67]. It forms when the iron molecule in hemoglobin is oxidized from $2^+$ (its normal state) to $3^+$. 

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