Quantifying Alopecia Areata via Texture Analysis to Automate the SALT Score Computation

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Quantifying alopecia areata in real time has been a challenge for clinicians and investigators. Although several scoring systems exist, they can be cumbersome. Because there are more clinical trials in alopecia areata, there is an urgent need for a quantitative system that is reproducible, standardized, and simple. In this article, a computer imaging algorithm to recreate the Severity of Alopecia Tool scoring system in an automated way is presented. A pediatric alopecia areata image set of four view-standardized photographs was created, and texture analysis was used to distinguish between normal hair and bald scalp. By exploiting local image statistics and the similarity of hair appearance variations across the pediatric alopecia examples, we then used a reference set of hair textures, derived from intensity distributions over very small image patches, to provide global context and improve partitioning of each individual image into areas of different hair densities. This algorithm can mimic a Severity of Alopecia Tool (score) and may also provide more information about the continuum of changes in density of hair seen in alopecia areata.

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INTRODUCTION

Alopecia areata (AA) is a common cause of nonscarring alopecia that occurs in a patchy, confluent, or diffuse pattern. AA has a reported incidence in the United States of 0.1−0.2% with a lifetime risk of 1.7%, with males and females being affected equally (Safavi, 1995). Accuracy in quantifying hair loss and regrowth is of paramount importance in standardization of patient care and for clinical trials. Current systems can be cumbersome, especially to those unfamiliar with them and, as a result, may limit users. We report an algorithm that can mimic the criterion standard tool, the Severity of Alopecia Tool (SALT), in an automated fashion.

The SALT score I (Olsen, 2004) is a global severity score that captures percentage hair loss. A recent update also incorporates some details of hair density (Olsen and Canfield, 2016). Estimating percentage for a SALT score, however, is time consuming and not easily done consistently with a quick visual assessment; interrater variability was noted among seven expert clinicians in the initial description of the tool (Olsen et al., 2004). A few other groups have reported other methods for assessing the density and diameter of hair using histologic images (Kim et al., 1999; Lee et al., 1995), but these methods were never translated into a practical tool. Finally, there also exists a proprietary image capture device, Trichoscan (Tricholog, Freigurg, Germany) (Hoffman, 2002), used to look at hair growth parameters, but it has not been validated for AA (Saraogi, 2010). Thus, there is a need for an automated way to quantitate hair loss in AA that mimics the criterion standard, SALT.

Computer-aided imaging has been used before to study scalp. In the earliest studies, Gibbons et al. (1986), reporting in the *Journal of Investigative Dermatology,* inferred the percentages of the hair-bearing versus non−hair-bearing areas of the scalp by thresholding a grayscale digitized photograph. However, since then, it has been widely published in the computer vision literature (Leung and Malik, 2001; Martin et al., 2004) that a simple threshold will most likely yield a crude estimate. Because distinguishing hair density more closely aligns with texture classification problems, a texture analysis methodology was used to delineate regions of normal hair, a spectrum of lower hair density, and bare/bald scalp.

Texture classification has been in the past successfully applied to distinguish materials like wood and paper (Cula and Dana, 2004; Leung and Malik, 2001; Schmid, 2001; Varma and Zisserman, 2005). These methods focus on classifying inherently different materials rather than different nuances of the same one. To detect hair in photographs of people, others, like Yacoob and Davis (2006) and Rousset and Coulon (2008) looked at spatial and color information. These methods were not directly applicable, however, because they focused on finding *hair* versus *not hair.* Although *scalp* and *hair* could be viewed as the different textures, the problem becomes more challenging when density or caliber of hair is considered. Although to our knowledge no computer imaging studies look at hair densities, studies related to skin nuances do exist. For example, Cula et al. (2005) extended the texture classification to model the appearance of skin by creating a database of skin textures

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Abbreviations: AA, alopecia areata; SALT, Severity of Alopecia Tool

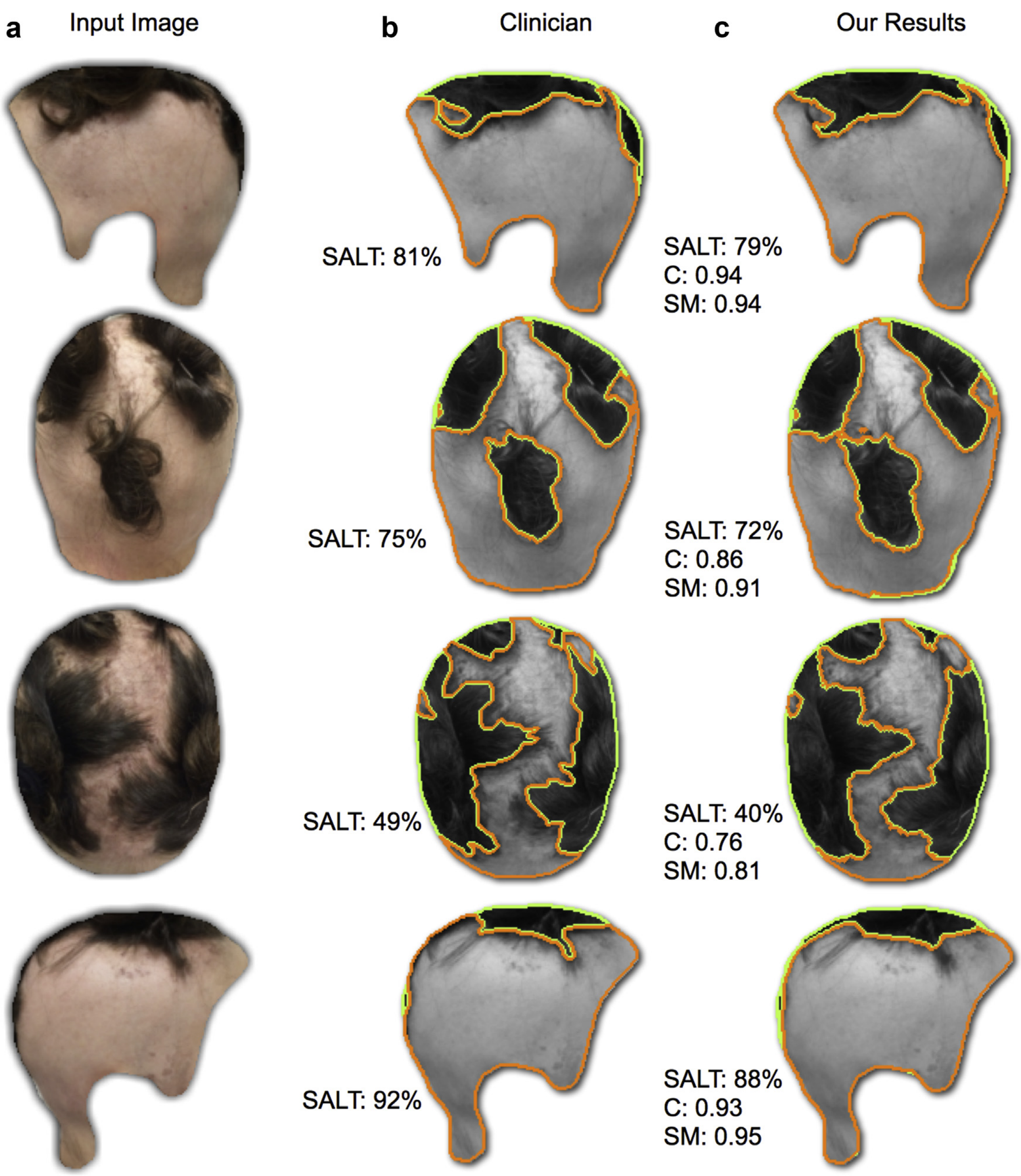

Figure 1. Automated SALT score results. Results for a sample patient with four image views. For each set, we show **(a)** original input image, **(b)** images manually annotated by an expert, and **(c)** machine output using the texture classification algorithm presented in this article. Regions where hair is completely absent are marked in darker orange. Regions with normal hair density are marked in green. For each image, we also indicate its SALT score, that is, the percentage of abnormal hair density, and the covering (C) and shape match (SM) used in the evaluations. SALT, Severity of Alopecia Tool.

measured at different illuminations and viewing angles. They used this to detect skin location on the face and to recognize human subjects based on their skin textures.

The texture analysis presented in this article was motived by the work of Koenderink and Van Doorn (1999), who introduced the idea of *locally orderless* images. They proved that taking neighborhoods of pixels and randomly permuting the intensity of the pixels within small neighborhood sizes did not affect the overall perception of the image as seen from a viewer. Here, texture units are defined based on local intensity statistics (Julesz and Krose, 1988) to create an algorithm for differentiating hair densities. As shown in the Results section, the presented method is able to identify regions of hair loss and normal scalp, thus also automating percentage hair loss.

RESULTS

In this article, we present an automated approach to the SALT score that was validated on a dataset of 250 images of more than 100 patients ages 2–21 years seen at the Children's Hospital of Philadelphia Dermatology Hair Clinic over a 1-year time period. The database included standardized input images together with full annotations by a hair expert. As detailed in the Methods section, an image database was created by taking four photographs of each subject using a standardized approach to image capture. Experts labeled the