Basic Concepts of the Bovine Teat Canal

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**ABSTRACT**

The bovine teat canal is highly specialized in its unique function of preventing both leakage of milk and entry of bacteria and thereby plays a major role in the defence of the udder against mastitis. The teat canal is a longitudinally folded cylinder-shaped body opening, covered with approximately the same type of epithelia as the normal skin and surrounded with a net-like integrated musculoelastic system facilitating its opening and closure. During milking, dead, flattened, nucleated squame (cellular detritus) are sloughed from the teat canal surface and are continually replaced by inner cells differentiating outwards.

The epidermis is characterized by a polarized pattern of epithelial growth and differentiation, with a single layer of proliferating keratinocytes and multiple overlying differentiated layers. Morphologically, the cells transit from the basal layers on the basement membrane of the dermis through *stratum corneum* before they finally end up as the keratin of the teat canal.

The majority of the epidermal protein synthesizing machinery is devoted to making keratin. This is reflected in the fact that keratins are the major structural proteins, constituting up to 85% of a fully differentiated keratinocyte. Epidermal keratin is a 40–70 kDa α-helical coiled-coil dimer of the intermediate filament family that, among other marker proteins, characterizes each stage of keratinocyte differentiation.

Studies of skin fragility disorders show that the primary role of keratins in epidermal cells is to reinforce them so that they do not lyse upon physical pressure and to provide cells with subtly different properties of resistance and plasticity to equip the epithelial cells for the physical stress of each particular body site.

Epithelial cell specialization for function also depends, however, on the lipid composition and organization and on the epidermal architecture. Epidermal architecture depends on epidermal turnover time, which in turn depends on cell number as well as the proliferative condition. Both *in vitro* and *in vivo* studies have implicated calcium as a major modulator of epidermal differentiation. Calcium is a factor known to enhance differentiation and promote expression of the differentiation-specific keratin genes. In animals and humans, both topical and systemic retinoids produce acanthosis, hypergranulosis and a relative (but not absolute) decrease in the thickness of the *stratum corneum*.

Despite a high degree of epithelial specialization, we expect a somewhat similar immunological functional importance in the teat canal epithelia as in other stratified squamous keratinized type epithelia.

**Keywords**: dairy cow, epithelial specialization, keratin, teat canal

**Abbreviations**: cAMP, cyclic adenosine monophosphate; DNA, deoxyribonucleic acid; EGF, epidermal growth factor; EGFR, epidermal growth factor receptor; GM-CSF, granulocyte–macrophage colony-stimulating factor; IF, intermediate filaments; IFN-γ, interferon-γ; IGF-I, insulin-like growth factor 1; IGF-II, insulin-like growth factor 2; IGFBP, insulin-like growth factor binding protein; IGFR, insulin-like growth factor receptor; IL-1, interleukin-1; IL-2, interleukin-2; IL-3, interleukin-3; IL-6, interleukin-6; KGF, keratinocyte growth factor; MHC, major histocompatibility complex; NEFA, non-esterified fatty acid; NSBK, non-serrated basal keratinocytes; PMN, polymorphonuclear leukocyte; pRB, retinoblastoma protein; SBK, serrated basal keratinocytes; SCC, somatic cell count; SCCe, *stratum corneum* chymotryptic enzyme; TGF-α, transforming growth factor; TGF-β1, transforming growth factor-β1; TGF-β2, transforming growth factor-β2; TNF, tumour necrosis factor
INTRODUCTION

The bovine teat canal – a one way valve

The bovine teat canal is highly specialized in its unique function of preventing both leakage of milk and entry of bacteria. All epithelial structures are characterized by their closely aggregated and tightly adherent cells and typically part of their surface is in contact with the environment. Teat canal epithelia have contact with the teat lumen environment. Teat canal epithelia are derived from the primary germ cell layer called ectoderm, just like the cells of the skin, the sensory receptors of the eyes, ears and nose, and the cells of the oral cavity. The function of this unique biological membrane is not limited to keeping water inside the body and keeping xenobiotics out, but also includes the role of sealant of the teat canal during the dry period and between milking. Teat canal keratin physically blocks the teat canal and thereby prevents penetration of potential mastitis-causing bacteria. The bovine teat canal (ductus papillaris mammae) is an invagination of the teat skin and has a structure that corresponds to a stratified squamous epithelium.

The superficial strata of this epithelium undergo keratinization and are eliminated as cellular detritus through the teat canal lumen during milking. The lining of the canal is thereby continually regenerated. To achieve the best possible protection, against both invading pathogens and the milking machine-induced mechanical forces acting on the teat tissues, the epithelium of the teat canal must be maintained in a quantitative and qualitative balance by the continuous proliferation and differentiation of cells throughout the lactation cycle.

The teat canal epithelium is highly specialized in its unique function. This functional specialization of the epithelial cells depends mainly on structural properties determined by the biochemistry of the keratin filaments and the epithelial adaptation to a rather unique cell turnover rate.

The objective of the present paper is to introduce the reader to the functional anatomy of the teat canal epithelia and the basic regulatory mechanisms controlling the turnover of teat canal keratin.

Clearly, the different objectives of human dermatological research, mostly concerning toxicological, cosmetic or medical matters, and the objectives of most bovine research, which have been primarily in the protective role of the teat canal, have not prevented interdisciplinary extrapolation of findings. As a consequence, significant parts of the present paper are derived from knowledge concerning human conditions. An increased understanding of teat canal epithelia may aid us in the study of the interactions between bovine teat defence, the milking machine and invading bacteria. The intention is that this paper will serve to broaden interest in the teat canal defence system. In the following, teat canal stratum corneum, as a whole, is referred to as teat canal keratin, while the intermediate filament is referred to as keratin.