ORIGINAL ARTICLES

Tissues And Organs Involved In The Non-Specific Defence Mechanism In Fish: A Review

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ABSTRACT

An efficient clearance and degradation system maybe needed during microbial invasion which otherwise would lead to severe inflammation and eventually death of fish. Non specific defense mechanism plays an important role at all stages of infection. Significant differences exist between the immune system of fish and mammals including the absence of bone marrow and lymph nodes in fish. The thymus, kidney and spleen are the principal lympho-myeloid tissues of teleosts. Liver, skin and intestine are also important components of fish defence system. Melanomacrophages in kidney, spleen and liver are considered to be the main scavenging cells towards non-self substances that are to be eliminated from the circulation. Macrophages play an additional role in the non-specific defence as well as in specific immunity by presenting antigen to immuno-competent cells and secreting non-specific humoral defence components and signaling substances. These highly phagocytic endothelial cells and macrophages are located in organs and tissues that constitute the reticuloendothelial system (RES). This review is essentially about the RES in fish.

Key words: reticuloendothelial system, lymphomyeloid tissues

Introduction

The immune system of fish is physiologically similar to that of higher vertebrates, despite certain differences. In contrast to higher vertebrates, fish are free-living organisms from early embryonic stages of life and depend on their innate immune system for survival (Rombout et al., 2005). Nonspecific immunity is a fundamental defence mechanism in fish Uribe et al. 2011. The immune response is a function of co-ordination among organs and their cellular subdivisions. The function of these organs is to indicate the types of antibodies for production in specific immune defence mechanisms, while in the non-specific immune defence mechanism specific antibodies are not produced. The kidney and spleen are the principal lymphomyeloid tissue in fish. Liver, skin and intestine are also important components of the defence system (Fange, 1984). Kidneys; spleen and liver are considered to be the main scavenging organs, where endothelial cells and macrophages highly endocytic towards self and non-self substances that are to be eliminated from the body. The thymus, kidney (anterior and middle) and spleen are the largest lymphoid organs in teleosts (Zapata et al., 2006). In freshwater teleosts, the thymus is the first organ to become lymphoid, but before this event, the anterior kidney may contain hematopoietic progenitors, but not lymphocytes (Lam et al., 2004). Thus, these cells located mainly in the Kidney and spleen are of importance in the RES (Aschoff, 1924).

Spleen:

In teleosts: the spleen is involved in haematopoiesis, the clearance of macromolecules scavenging antigen degradation and processing and the production of antibody. The role of the spleen in the, nonspecific and specific defence system is thought to be secondary to that of the anterior kidney (Farren, 1967). The ellipsoids in the spleen of teleosts have repeatedly been demonstrated to trap different particulate and non particulate substances such as old cells, pathogens and/or protein aggregates. LPS and B (1,3)-D-glucan,(Ellis et al., 1976; Secombes and Manning, 1980; Dalmo et al.1995). The spleen is mainly composed of blood cells, endothelia cells, reticular cells, macrophages and melanomacrophages (Graf and Schlun's, 1979).

Kidney:

The kidney is the major blood forming (haematopoietic) organ in fish (Zapata, 1979); Bielek, 1981). Both the anterior (head kidney) and the posterior kidney (hind kidney) are haematopoietic sites. The morphology of the kidney differs within the teleost fish, as reviewed by Rowley et al. (1988) but in general, the kidney is

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mainly composed of blood cells at different stages of maturation, endothelial cells and cells participating in excretory and endocrine functions (Zapata, 1979; Dannevig and Lavue, 1994). The kidney in teleost fish is the equivalent of the bone marrow in vertebrates and is the largest site of haematopoiesis until adulthood (Zapata et al., 2006). The melanomacrophage centres are macrophages that contain melanin, ceroid and lipofuscin pigments. According to Robe (1975), these melanomacrophages appear to be organized in aggregates in other teleosts. The precise function of the pigment containing phagocytes or melanomacrophage centres in the defence system of teleost is still unknown (Wolke, 1992). The uptake of substance by kidney cells has been detected following the injection of formaldehyde treated with human serum albumin (Smedarod et al., 1984), bacterial lipopolysaccharide (LPS) (Dalmo et al., 1995), and connective tissue proteins, (Smedaro et al., 1993) and carbon in the kidney and spleen (Adedeji and Kakulu, 2011). The clearance of such substances is an important function of the RES (Aschoff, 1924; Smedro, 1980), Endocytosed molecules may be subjected to intracellular degradation (Dannvig and Berg, 1978; Smerdsrub, et al., 1984), and/or excretion via glomeruli and tubules to the urinary bladder (Christiansen et al., 1996). Antigenic substances may be processed and presented to T-cells by antigen presenting cells (APC; i.e. macrophages and B-cells), thereby initiating specific, immune response (Vallejo, et al., 1990).

Liver:

The liver of fish plays a minor role in the defence system. However, reports have shown that the liver also has as scavenging role in the RES in fish but is considered not to be as efficient as the kidney and spleen in salmonids, and the heart, spleen and kidney in other marine fish. Liver macrophages (Kupffer cells) have been described in certain teleost species (Salmo gairdneri, Ictalvarus punciatus and Carassitus avratus) on the basis of morphological criteria (Hampton, et al., 1987). However, there is common agreement that Kupffer cells are rare or absent in other teleost fish (Dalmo et al., 1995).

Heart:

Macknall and Michels (1933) reported that the endocardial cells of the heart were loaded with carbon particles after intraperitoneal (i.p.) injection of colloidal carbon into a marine teleost, Tavtologlabrus adsparus. They suggested that these endothelial cells were subsequently transformed into macrophages.

Ellis et al. (1976) found-atrial uptake of colloidal carbon in the plaice Plaveronectes platessa. Nine hours after administration, some of the endocardial cells, full of carbon appeared to be rounding up and floating off (Ferguson, 1976), Ellis et al. (1976) also recognized that carbon-containing cells of the atrium were rounding up and might be in the process of becoming free macrophages. They suggested that phagocytes in the heart migrate to other organs presumably via the circulation after taking up carbon particles. In contrast, Mori (1980) reported that carbon particles were trapped in hear endocardia in gold fish after i.p. injection. Beyond a role as a scavenger of foreign substances, the immunological function of the highly endocytic endocardial cells remain to be investigated.

Skin:

The skin, with its scales and surface mucus, provides a protective physical barrier that is important in terms of both osmoregulation and pathogen defense Claudia and Jeffrey (2009). Flakes, skin mucus and gills act as the first barrier to infection (Ellis, 2001). A layer of mucus (glycoproteins proteoglycans and proteins) forms the interface between the skin of the fish and the external environment, in addition to scales in some fishes, for example, tilapia. This mucus layer which is continually replenished by mucus secreting cells, inhibits the colonization of the integument of the fish by potentially harmful microorganisms. The rate of mucus secretion can increase in response to infection or to chemical and physical irritants (Santos and Hall, 1990 Yang and Albright, 1994; Nilson, 1995) Lysozyme, (Fletcher and White, 1973) and another bacteriolysin (Ourth, 1980) are known to be present in the mucus of fish skin (Plaice and Channel catfish respectively). The complement cascade is also considered important as an anti-microbial system in skin mucus. Furthermore, the migration of epidermal phagocytic cells from the periphery of a wound over the wound surface has been observed in fish skin (Bullock and Marks, 1978).

Intestine:

The gastrointestinal tract is also a barrier for microbial invasion. The digestive function of the gut provides an extremely hostile environment to potential pathogens by virtue of the low pH. (in species with an acid stomach), and the secretion, and action of digestive enzymes (e.g. trypsin and pepsin) and bile (Dabrowski and Glogowski, 1977; Kristjanson and Nielsen, 1992).
In teleost fish Payer’s patches and M-cells, (M-cells, i.e. specialized epithelial cells) which are in the follicle-associated epithelium of Payer’s patches are absent. However, intraepithelial lymphocytes and macrophages together, with eosinophilic granular cells situated in the lamina propria, are present (Smith, 1975; Sveinbjornsson et al., 1996). Dalmo et al. (1995a) showed that microparticles (0.045-1µm) were not absorbed by the intestine in Atlantic salmon. These findings did not confirm the result of Tamura et al. (1993), who reported that phagocytosis of fixed *Vibrio anguillarum* occurred in the intestine of eel.

The posterior part of the intestine is considered to be the main site or intestinal absorption of macromolecules in salmonids and in some other fish species (Dogget et al., 1993; Sveinbjornsson et al., 1995). The intestine of the stomach-less fish (Cyprinids) such as grass carp, *Ctenopharyngodon idella* (Valenciennes) showed regional functional differentiation in respect to absorption of macromolecules (Stroband et al., 1979). Absorption occurred when macromolecules such as ferritin horseradish peroxidase and immunoglobulins were introduced to the intestine (McLean, and Donaldson, 1990). In the immature intestine of fish larvae, introduced macromolecules such as proteins and, B, (1,3)-D-glucan are found to be absorbed mainly from the posterior intestine. It has also been shown that in Brown trout and Atlantic salmon, *Salmo salar* that the anterior intestine is also capable of absorbing macromolecules (Dalmo et al., 1996b). Thus we can conclude that the whole intestine has the ability to absorb macromolecules.

**Other Tissues:**

Leucocytes are also distributed in the gills, heart and regions which are rich in connective tissues (Ellis et al., 1976; Ainsworth, 1992). It is presently considered that these tissues, are so important in the immune system as the activity of the kidney, spleen and thymus.

However, it should be emphasized that elements (antibacterial substances such as lysozyme and complement) of the non-specific defence system are widely distributed in the tissues of fish.

**Conclusion:**

Aschoff (1924) introduced the term the ‘reticuloendothelial system’. He included in the definition of all cells contributing to the clearance of blood of both endogenous and exogenous substances. In mammals, the sinusoidal endothelial cells of the liver, spleen and bone marrow are thus a central of the RES. Also, the macrophage phagocyte system is a part of the reticuloendothelial system clearing the blood of non-particulate and particulate matter and cells. In Salmonids, the kidney macrophages and sinusoidal endothelial system cells seem to correspond to the mammalian hepatic reticuloendothelial cells concerning the clearance of circulatory collagen (Smedsrod et al., 1993). Following intravenous injection of colloidal carbon and yeast cells (Ferguson, 1976) and i.p. injection of colloidal carbon (Ellis et al., 1976), considerable amount of the inject substances accumulated in endothelial cells of the atrial endocardium of the plaice. Smedsrod et al. (1995) found that circulating collagen accumulated in cells lining the endocardial blood space of both atrium and ventricle in cod. They concluded that these cells resemble the sinusoidal endothelial cells of salmon kidney and mammalian liver.

The endocardium of some fish is clearly responsible for the clearance of both endogenous and exogenous substances. Ferguson (1976) found yeast particles in cardiac endothelial cells in plaice and suggested that the cells were actively phagocytic. Obviously, there must be high inter-species differences as many cod endothelial cells did not show avid phagocytosis of latex beads (Smedsrod et al. 1995).

Finally, it is important to find out if, the endocardium of fish have other functions such as antigen presentation apart from clearance of endogenous and exogenous substances.

**Reference**


