



## Bovine hypodermosis: A review

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### ABSTRACT

**Cattle hypodermosis (warble fly infestation, WFI) is an economically important disease in livestock throughout the world. Larvae of *Hypoderma* spp. cause subcutaneous myiasis of domesticated and wild ruminants. The important species in cattle are *Hypoderma bovis* and *Hypoderma lineatum* whereas, *Hypoderma diana*, *Hypoderma actaeon* and *Hypoderma tarandi*, affect roe deer, red deer, and reindeer, respectively. *Hypoderma crossi* infects sheep and goat. Adults of the cattle grub are commonly known as heel flies, warble flies, bomb flies or gad flies. The larval stages of *Hypoderma bovis* and *Hypoderma lineatum* are commonly called 'ox warbles'. The biology of hypodermosis is complex in nature. The parasitic larval stage of *Hypoderma* spp. spend about one year in domesticated as well as in the wild animals, while the adult free-living stage lasts only for few days. The disease causes heavy economic losses to animal production like milk and leather industry. It can also affect the general health status as well as the immune system of the body of the diseased animals. The early diagnosis of hypodermosis is of great importance for planning treatment and eradication program. The control measures of the disease have been efficiently practiced and consequently this disease is controlled at national level in many European countries. Keeping in view the importance of the disease, the present review intends to underscore and provide up to date information about the overall aspect of hypodermosis in animals with the existing literature available with special emphasis on hypodermosis on cattle.**

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## INTRODUCTION

Warble fly infestation is a major disease of economic significance affecting livestock throughout the world. The warble has an Anglo-Saxon origin which means boil

(Scholl, 1993). Larvae of *Hypoderma* spp. cause a subcutaneous myiasis of domesticated and wild ruminants. The definitive hosts for this parasite are

**Table 1.** Prevalence rate of hypodermosis in cattle globally.

Country	Prevalence rate (%)	Host	References
UK	40	Cattle	(Webster, 1998)
Turkey	3.56-10.23	Cattle	(Gulanber et al., 2000)
Kazakhstan	30	Cattle	(Mukhtar and Omarkhan, 2004)
Albania	38.66-41.28	Cattle	(Otranto et al., 2005)
Turkey	31.9	Cattle	(Kara et al., 2005)
Turkey	23.3	Cattle	(Simsek et al., 2008)
Turkey	2.96	Cattle	(Cicek et al., 2011)
Turkey	28.9	Cattle	(Karatepe et al., 2013)

herbivores including cattle, buffaloes, sheep, goats, deer and reindeer. There are seven species of *Hypoderma* that affect the wild and domesticated animals and these are *Hypoderma bovis* (Northern cattle grub), *Hypoderma lineatum* (common cattle grub), mainly affecting cattle, *Hypoderma diana*, *Hypoderma actaeon*, *Hypoderma tarandi*, *H. sinense* affecting roe deer, red deer, and reindeer respectively (Taylor et al., 2016) and *Hypoderma crossi* of sheep and goat (Scholl, 1993). The disease has been extensively studied all over the world due to its high economic significance. It has been reported from almost all countries rearing livestock. Many scientists in the past worked on the epidemiology, economic significance and control of hypodermosis in Europe including the eastern European countries of the former USSR and Asia. It has been observed that the parasite is unable to adopt the seasonal life cycle to the conditions of Australia and South Africa due to the climatic conditions (Tarry, 1998).

During the recent decade, livestock production has increased significantly. However, still this sector has not yet reached its full potential to deliver adequate meat for the rising human population across the globe (Thornton, 2010). Among several restraining factors, parasitic diseases that severely affect livestock are the biggest constraints. Among parasitic diseases, ectoparasitic infestation is a serious veterinary health problem affecting livestock industry, worldwide (Hourrigan, 1979). *Hypoderma* spp. under the family Oestridae is responsible for causing subcutaneous myiasis that affects both wild and domestic ruminants across the northern hemisphere (Boulard, 2002). This is an endemic disease of livestock (including goats, deer, buffaloes, yaks and cattle) which results a severe decline of milk and meat production and depreciation in hide quality from holes and other flaws caused by *Hypoderma* larvae (Hall and Wall, 1995).

Only one species viz., *H. lineatum* has been described from India affecting the bovidae with a prevalence rate of 50–90% (Soni and Khan, 1945) and Yadav et al. (2013) reported prevalence rate (9.73%) of *H. lineatum* in case of cattle from Jammu state by conventional palpation method.

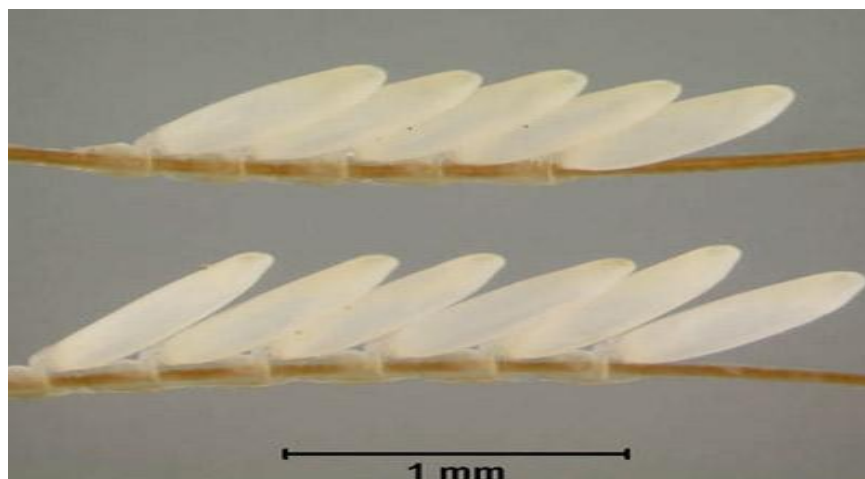
## GLOBAL DISTRIBUTION

*Hypoderma* spp. have cosmopolitan in distribution but more commonly found in tropical and subtropical countries of the world. The prevalence of disease due to *Hypoderma* varies in different regions of the world and upon the region studied (O'Brien, 1998; Scholl, 1993; Martinez-Moreno et al., 1992). In many countries, the rate of infestation was reported up to 100% in different herds that might be due to a great variation between the parasitological and immuno-diagnostic techniques for the detection of hypodermosis. It might reflect differences of antibody-mediated host immune responsiveness in different species of animals (Frangipane di Regalabone et al., 2003). The prevalence rate of hypodermosis varies depending upon diagnostic methodologies used ranging from 21 to 79% in Spain, 43% in Belgium, 85% in Italy (Puccini et al., 1997; Preston, 1984; Frangipane di Regalabone et al., 2003), while it was 44.2% in Greece (Papadopoulos, 2004). In East Turkey, 28.6% cattle were found seropositive for hypodermosis (Balkaya et al., 2010). Similarly in Middle East, the disease has prevalence rate of 14.1% in Libya (Otify and Mansour, 1994) and 23% in Iraq (Abul-Hak, 1973). South East Asian countries like China have a record of 80% (Yin et al., 2003) and 18.4% in Pakistan (Ahmed et al., 2012). Yadav et al. (2013) reported prevalence rate (9.73%) of *H. lineatum* in case of cattle from Jammu state of India. The prevalence rate of hypodermosis in cattle across the globe is shown in Table 1.

## Oviposition and egg development

The egg laying of *H. lineatum* and *H. bovis* varies

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**Figure 1.** Egg of *H. lineatum* (Photograph by Lyle J. Buss, University of Florida).

significantly so does its ovipositing behaviour (Andrews, 1978; Colwell, 1992; Scholl, 1993; Tarry, 1998). Both species also differ from each other in approaching the animals, egg laying behaviour, egg size, phenotype and migration pattern in the affected host, etc. (Scholl, 1990). Mating occurs soon after the flies emerge and females begin to lay eggs within 20 min after copulation.

### Eggs, skin penetration and larval development

Eggs of *H. lineatum* are 1 mm in length and are laid in a row of six eggs and attached by a petiole to the hairs below the hocks (Figure 1) (Tarry, 1998) while in case of *H. bovis* the eggs are laid singly on the body and above the hocks of the animals (Urquhart et al., 1991) and the egg production ranges from 500 to 800 (Andrews, 1978). The body temperature of the animal influences the hatching of eggs but it normally takes place within 3-7 days (Pruett and Kunz, 1996). The first instar of *Hypoderma* larvae is about 1 mm in length and the skin of the affected animals plays an important role as an important mechanical barrier to *Hypoderma* larvae, especially in the previously infested animals. The entry of larvae into the tissue occurs through the hair follicle and this is aided by the use of proteolytic enzymes and the paired mouth hooks. The proteolytic enzymatic secretions of *Hypoderma* spp. are of three types, for example, HyA, HyB and HyC (Ahmed et al., 2016). These enzymes are secreted by the blind midgut (Lecroisey et al., 1979). The penetration in the skin of the host is completed within 6 h after hatching (López et al., 2005). In case of older and previously sensitized animals, oedema and inflammation at the site of penetration was observed which in turn lead to many death of the first instar larvae of *Hypoderma* (Gingrich, 1982). The migratory pattern of *H. bovis* and *H.*

*lineatum* larvae in the body of affected animals varies. In case of *H. lineatum*, larvae travel through the submucosal connective tissues of oesophageal wall of the body and ultimately reach at the back of animals while in *H. bovis* it travels along the nerve paths and reaches into the spinal canal. The migration of the larvae inside the body of host is again aided by the proteolytic enzymes secreted from the anterior part of the larvae (Scholl, 1993).

The larvae move in the resting site of the body of the host in different ways in both species of *Hypoderma*. In case of *H. lineatum*, the larvae travel in the loose submucosal tissue of the esophagus while in *H. bovis* the larvae move towards the similar resting site in the epidural fat between the dura mater and periosteum in the spinal canal (winter resting site). At this stage, the first instar larvae are approximately 15 mm in length; these larvae then move towards the mid-dorsal area of the host (Figure 2). Here they moult to the second instar and increase considerably in size (spring resting site). It takes about 30-60 days to complete this phase (Scholl, 1993).

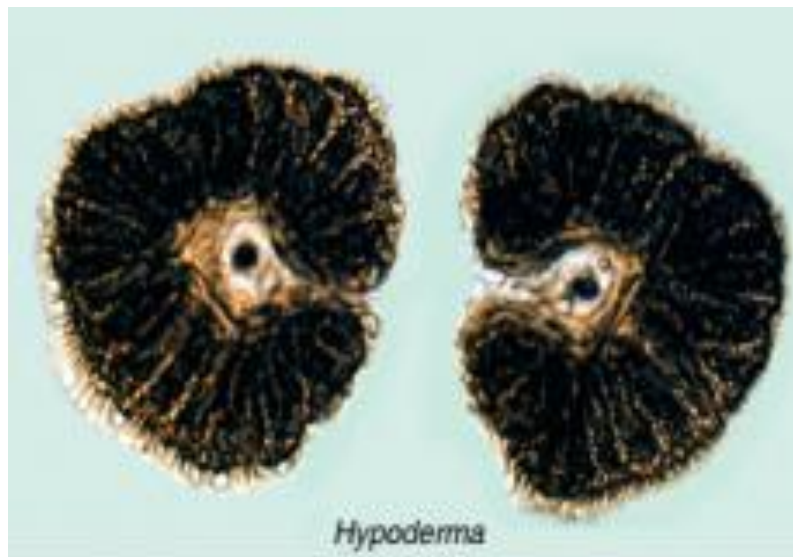
At this stage, characteristic raised skin nodules are formed, which are called warbles. The larvae cut a hole in the skin of animals and direct their posterior part towards these holes for the purpose of respiration. The larvae are armed with backwardly pointing spines which make difficult manual removal of the larvae at this stage (Zumt, 1965). The larvae moult to the third stage and during this time they reach approximately 30 mm long and when mature they fall to the ground and pupate. The spiracles of *Hypoderma* spp. larvae are characteristically 'fan shaped' with numerous radiating slits (Figure 3).

### Pupation

The pupa of *H. bovis* has been found burrowing beneath



**Figure 2.** Larva of *Hypoderma* spp. (Melhorn, 2008).



**Figure 3.** Spiracle of *Hypoderma* (Bowman, 2014).

loose soil. The length of time from pupa to adult varies from 2 to 8 weeks. The flies emerge mostly from March to June depending upon species and climatic conditions and continue the life cycle (Zumpt, 1965; Reina et al., 1995; Panadero et al., 1995; Navarrete et al., 1993). In *H. lineatum*, in spring, the mature larvae wriggle out of the cysts and fall on the ground, where they penetrate the soil and pupate. Pupation is almost immediate. The maturation of the adult does not occur if the moisture content is higher than 10 percent. The pupal case is black and the fly emerges from it after 35 to 60 days by pushing open an operculum at the anterior end.

### **Adult**

Immediately after emerging the adult flies crawl towards the site where the wings are expanded and hardened. The life span of both male and female adult fly is very short, for example, from 3 to 7 days but the adult fly may live up to 10-15 days in the controlled environment (Kettle, 1990). The adult fly has an interesting part of life during its copulation in that the adult male waits for the female at the sites of mating (Catts et al., 1965). The female warble fly mates only once during her life span. After mating, the flies lay their eggs on the hair of the



Figure 4. Adult *Hypoderma* fly (Bowman, 2014).

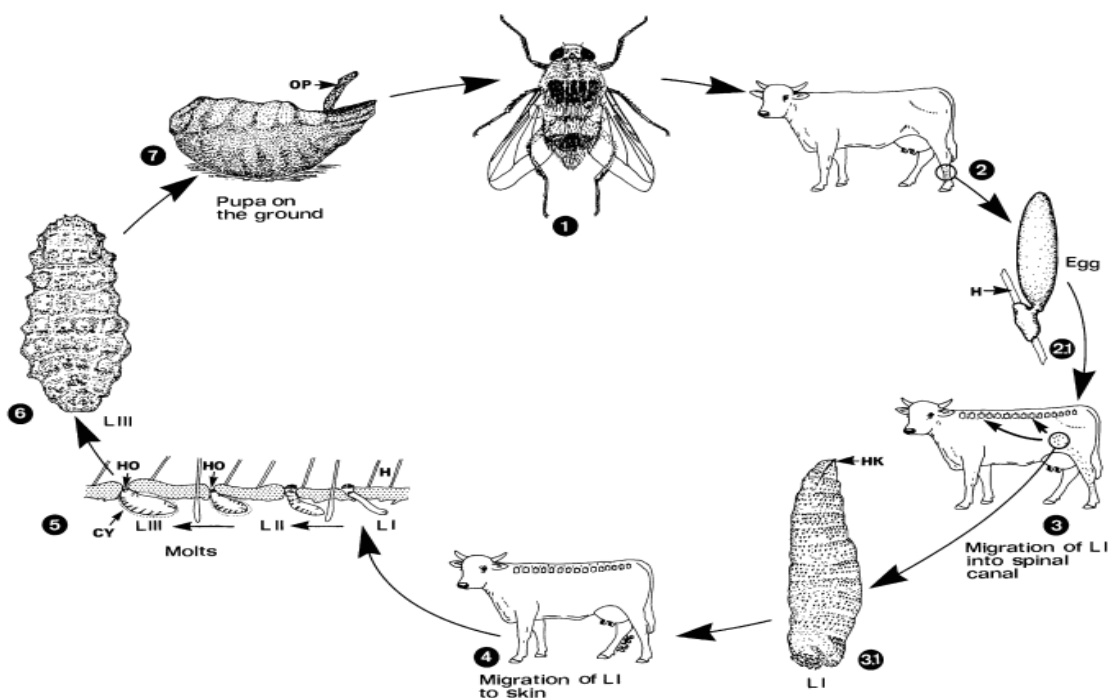


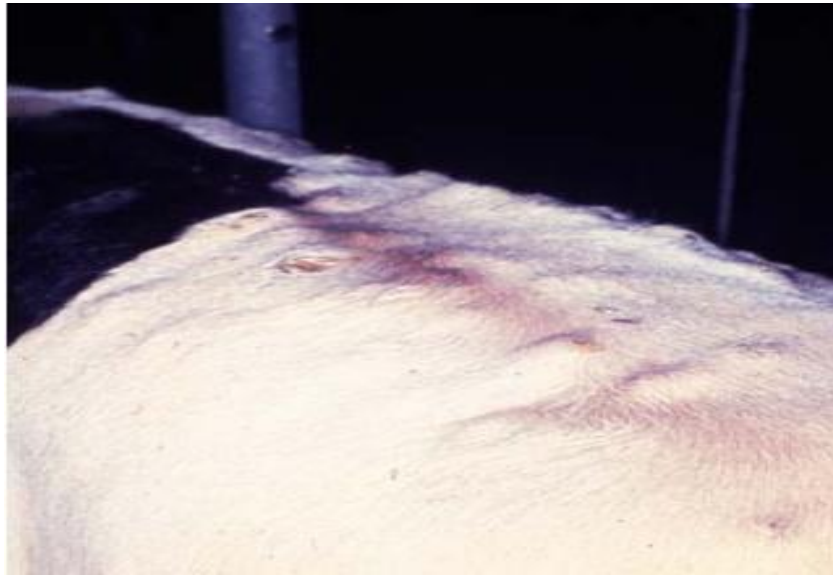
Figure 5. Life cycle of *Hypoderma* spp. (Melhorn, 2008).

legs, flank, or the back of animals. Adult male dies soon after mating while female die after the laying of eggs (Scholl and Weintraub, 1988). Adult flies of both species are hairy, the head and thorax is yellowish white in *H. lineatum* while greenish to reddish yellow in *H. bovis* (Figure 4). The adult flies which have no functional mouth parts and look like bumble-bee are short lived, living only 3-5 days (Kettle, 1990). Both species are univoltine and *H. lineatum* adults can be found in Europe from March

until the end of May, while *H. bovis* adults emerge from June to mid-September (Tarry, 1980). The schematic diagram of life cycle of *Hypoderma* spp is shown in Figure 5.

**ECONOMIC IMPORTANCE**

When the flies approach to lay eggs the cattle become



**Figure 6.** Hide damage by warble fly (Melhorn, 2008).



**Figure 7.** Licked beef condition in red deer carcass (Scotland) (Stock image, Diomedia).

nervous and attempt to escape the attack by running away, and will even go into water. This condition is called gadding. Because the flies are persistent in laying eggs, the animals are constantly restless and do not feed or rest properly, which results in an appreciable loss of weight and decrease of milk production. In addition, the animals may also injure themselves severely, or at least become wounded and damage their skins (Soulsby, 1982).

Warble fly infestation is considered one of the most economically important ectoparasitic diseases of cattle,

goats and sheep (Hall and Wall, 1995). The factors that contribute economic losses due to hypodermosis include damage to hides (Figure 6), gadding, decrease in milk production, carcass depreciation resulting in the butcher's jelly or licked beef (Figure 7), etc. (Macchioni, 1984). These economic effects are either of direct effects like reduction in the weight gain and milk production that is due to the activity of the adult fly and the grubs within the host or the indirect effects due to migration of grubs through tissues and the grubs present on the back of the affected animals (Colwell, 1992). Amongst all these

effects caused by the *Hypoderma* spp., hide damage is one of the most important one (Tarry, 1986).

Actually, this particular cost has often been borne by farmers in the all-in price for cattle at slaughter and the damage can necessitate the expensive import of unaffected hides from other countries where the problem does not exist (Tarry, 1998). The migrating larvae in the affected host are responsible for the greater part of the cost of disease. In the last decade, many workers have reported the weight loss due to the warble fly infestation when compared with uninfected animals. Another very important effect of hypodermosis is the immunosuppression in the infested animals (Chabaudie and Boulard, 1992; Nicolas-Gaulard, 1995) that enhances the chance of secondary bacterial, viral or other parasite infections and it is extremely difficult to evaluate these losses economically. This disease also damages the host's immune system that impairs both the inflammatory and the specific immune systems of the affected animals (Boulard, 1989; Chabaudie and Boulard, 1992). In countries, where the livestock industry makes up a significant part of the economy, the national costs of these losses are incalculable.

The economic losses have been estimated in many countries in the past. In USA, the loss was estimated at least \$192 million in 1972 (Khan, 1977) and 100 million shillings in 1965 in Austria (Kutzer, 1984). In Greece, the net economic losses were calculated 119 million annually while in Italy \$11.5 million per annum was estimated (Macchioni, 1984).

## IDENTIFICATION OF *HYPODERMA* SPP.

### Stereo microscopy

*H. lineatum* differs morphologically from *H. bovis* according to body colouration and distribution of spine on third stage larvae body segment which can be distinguished easily under stereo microscope (Scholl, 1993). Adults *H. bovis* and *H. lineatum* are covered with hair but differ in body coloration for example *H. bovis* is greenish to reddish yellow and *H. lineatum* is yellowish white (Kettle, 1990). Each segment of the third stage larvae bears a number of flat tubercles and small spines are present on all segments but in the last in *H. lineatum* and on all but the last two in *H. bovis* (Soulsby, 1982).

### Electron microscopy

Colwell et al. (1998) described the accurate structural morphological identification of four *Hypoderma* spp. (*H. diana*, *H. bovis*, *H. lineatum* and *H. actaeon*) in Yak China by using scanning electron microscopy. The cephalic segment contains mouths and opercular sutures

with spinal bands in between in cattle. In yaks, among these three species, no morphological difference in shape of grub's heads has been found. In *H. bovis* the spiracular plate is concave and contains many spines at the opening rims while in *H. lineatum* the spiracular plates are flat with no spines. On the other hand the spiracular plate of *H. sinense* is flat like that of *H. lineatum* but it contains small and fewer spines. The spinal band is absent in the tenth segment of the warble body of *H. bovis*, but *H. lineatum* has a single band at the posterior border on the tenth ventral segment. *H. sinense* has two spines bands at both the anterior and posterior border of its tenth segment. Scanning electron microscopy has also been used to identify *H. lineatum* on the basis of general morphology, antennae of males/females and size, type, distribution, ultra structure of sensilla (Li et al., 2015).

### Molecular discrimination

In recent years, cytochrome oxidase I (COI) of the mitochondrial DNA (mt-DNA) has been increasingly used as a potential target gene for a number of molecular phylogenetic and identification studies. Its size (~1500 bp) and the presence of both highly conserved and variable regions with a range of closely associated mutational rates (Lunt et al., 1996) make COI ideal for such purposes. Its utility as a global molecular clock gene has recently been demonstrated by Gaunt and Miles (2002). An RFLP assay (*TaqI*, *RsaI*, *HpaII*, *HaeIII*, *TruI*, *HinfI* enzymes) of COI gene of most common Italian species of Oestridae (for example, *Gasterophilus intestinalis*, *Oestrus ovis*, *Przhevalskiana silenus*, *H. bovis*, *H. lineatum*) has demonstrated a clear genetic difference between these species. However there is no interspecific variation in restriction fragment length polymorphisms (RFLPs) between two species of *Hypoderma* (Otranto et al., 2000).

The molecular differentiation of *H. bovis* (Otranto et al., 2000; Boulard et al., 1996) and *H. lineatum* (Colwell et al., 1998) (Diptera, Oestridae) was carried out by the amplification of variable region of COI gene by polymerase chain reaction (PCR) and the sequenced analysed the resulting amplicons. The differential profile generated by restriction digestion using *BfaI*, *HinfI* and *TaqI*, was used to demarcate *H. bovis* and *H. lineatum* due to their different inter-specific variation rates (Otranto et al., 2003). Similarly, mitochondrial COI genes were used as a probe to identify species by PCR-RFLP in eastern Turkey. *H. bovis* and *H. lineatum* third instar larvae (L3) were differentiated by 438 and 250 bp bands and 488 and 200 bp bands, respectively; while only *TaqI* enzyme was used in this study as compared to previous studies (*BfaI*, *HinfI* and *TaqI*) (Balkaya et al., 2010). Thus the COI gene region examined was useful for the

**Table 2.** Serological techniques.

Name of the techniques	Description
1. Proteolytic enzymatic secretions	It is based on the proteolytic secretion from <i>Hypoderma</i> larvae that is, Hypodermin A, Hypodermin B and Hypodermin C. These enzyme has been widely used in serodiagnosis of bovine hypodermosis for detection by serological tests (Ahmed et al., 2016)
2. ELISA bioassay	
i) Indirect ELISA	ELISA based detection is considered a gold standard for the detection of <i>H. bovis</i> in infested animals due to its high specificity and sensitivity (Cencek and Ziomko, 2001)
ii) Competitive ELISA	
iii) Recombinant Hypodermin C based ELISA	
3. Immunological responses	
i) Local and systemic cytokine response	B cells, IgG plasma cells and CD3+ infiltrates were more abundant in previously infested animals (Lopez et al., 2005). Immunohistochemistry and sandwich ELISA was used to determine the production of interleukin 10, interleukin 4 and interferon gamma (IFN- $\gamma$ ) (Ahmed et al., 2016)
ii) Ag. sensitive lymphoproliferative response	Cattle infested with the common cattle grub, <i>H. lineatum</i> develop specific humoral antibodies and a cellular immune reaction, defined by delayed-type hypersensitivity, to purified <i>H. lineatum</i> proteins (Ahmed et al., 2016).
iii) Cellular and humoral response	Involvement of different immune cells is observed in various cases. The CD4+ T-helper cells and CD8+ CTLs cells are found in primary infection by <i>Hypoderma</i> larvae (Dacal et al., 2011)

differentiation of *H. bovis* and *H. lineatum* and that a PCR-RFLP assay is a practical tool for their identification, offering additional diagnostic and epidemiological information for the study of cattle grub infestation.

## DIAGNOSIS

In an infested area, the planning of a program for treatment and the eradication of bovine hypodermosis is based on timely diagnosis before damage takes place (Boulard et al., 1996; O'Brien, 1998; Otranto, 2001). This approach is widely used to monitor the efficiency of eradication campaign. It is suggested that at low infestation levels the clinical diagnosis is impractical (Iqbal, 1994; Webster et al., 1997; Colwell, 2000).

### Conventional procedure

The traditional method for detection of hypodermosis is based on palpation method. Generally, the bovine hypodermosis is diagnosed by the inspection of nodules in infested cattle during summer and spring season (depending on the region), see Table 2 (Ahmed et al., 2016).

## CONTROL AND ERADICATION

### Mechanical removal of larvae

Mature larvae may be squeezed out of the warble swelling. This is more successful when the larvae are

mature. Rupture of the larvae during extraction may lead to a localized inflammation and abscess formation (Soulsby, 1982).

### Insecticide treatment

With the advent of systemic organophosphorous insecticides in the 1950s cattle grubs control becomes reality on a large scale at a reasonable cost. The use of systemic insecticides facilitates control of larvae in the early stages of migration and before they reach the backs of the animals. The insecticides are used during the autumn and early winter with the aim of killing the younger larval stages. The compounds may be given orally, or in dips, sprays, drench or bolus form, but most convenient is "pour on" dressings in which a small volume of concentrated insecticide is poured along the animal's back. Enough insecticide is absorbed through the skin to kill the larvae. These compounds should be avoided in January and February because severe reactions may occur due to the death of larvae in the wall of the esophagus or spinal canal. The host-parasite reaction is best treated with sympathomimetic drugs (for example, adrenaline) and steroids to alleviate local inflammatory reactions. Atropine, the antidote for cholinesterase-inhibiting agents, is contraindicated; host-parasite reaction is not a manifestation of organophosphate toxicity even though it may be precipitated by organophosphate medication.

Drinking water treatments of insect growth regulators generally do not prevent cattle grub larvae from reaching backs of cattle, but may prevent adults from enclosing from pupae, thus preventing reproduction. An insecticide-



**Table 3.** Potential immunogenic protein can be used as vaccines candidates for *Hypoderma* spp.

Year	Vaccine composition	Source	Outcomes	References
1970	Crude collagenase	First-instar <i>H. lineatum</i>	Resistant	(Magat and Boulard, 1970)
1991	Native or denatured HyA,	First-instar <i>H. lineatum</i> HyA-specific	Responses were highly variable and weak	(Fisher et al., 1991)
1991	HA antigen alone or with adjuvants	<i>Hypoderma</i> spp	No significant protection	(Chabaudie and Boulard, 1991)
2011	Larvae Fat Body, haemocytes and haemolymph and Quil A as an Adjuvant	3rd Instar	100% Mortality	(Colwell, 2011)

impregnated plastic strip applied to legs of cattle during the heel fly season prevents the appearance of cattle grub larvae in backs of treated cattle.

*Hypoderma* infection is treated most commonly these days with the systemic macrocyclic lactone like ivermectin, doramectin, eprinomectin, or moxidectin (Davey and George, 2002). Eprinomectin and moxidectin pour-on can be used for treating both beef and dairy cattle. In the early 1980s this antiparasitic compound was established as one of the most effective materials ever developed for systemic use against cattle grubs. This product possesses unique characteristics not seen in organophosphorus systemic. The first of these is an ability to kill migrating larvae, but unlike systemic, it is also highly efficacious at extremely low dosages against second- and third-instar larvae in warbles. The latter activity permits use of this material as a late-season or pour-on treatment for grub-infested cattle that is not possible with traditional systemic insecticides, which are not effective, once the larvae are inside their warbles.

In cases in which preventive treatment has been neglected, late second-stage and third-stage *Hypoderma* larvae can be safely and quickly removed from the backs of cattle by slowly injecting 1 mL of 3% hydrogen peroxide solution into the breathing hole using a blunt cannula or needle shank of the syringe and taking care not to pierce the grub. Most grubs will emerge within 15 s after the foaming action of the hydrogen peroxide begins and leaves behind a cleansed cavity (Scholl and Barrett, 1986).

## Vaccines

The development of vaccines against *Hypoderma* spp. has been relatively slowed for more than 10 years despite the rapid development of genomic and proteomic analysis and of skills in data interpretation (Sandeman et al., 2014). Cattle develop resistance to *Hypoderma* spp. following repeated exposure to natural infestations

(Gingrich, 1982; Baron and Weintraub, 1986) and artificial exposures (Pruett and Kunz, 1996; Colwell, 2001). It has been found that fewer *Hypoderma* spp. larvae appear in the back of older cattle than in calves or yearlings, which indicates the development of some type of immunity in older cattle.

Promoting resistance is one of the big challenges in vaccinated cattle with 1st instar secretory proteins (Baron and Weintraub, 1986; Baron and Colwell, 1991; Boulard, 2002). The immuno-reactive portions of bovine immunoglobulin survive exposure to extracorporeal larval enzymes, as well as transit of the midgut, and pass through epithelial cells to enter the larval haemocoel (Colwell and Leggett, 2004). The efforts towards determining the mechanism of immune response of different *Hypoderma* spp. and vaccine development has been carried out in many countries (Scholl, 1993). Initially, crude extract of *Hypoderma* spp. larvae was used as vaccine (Colwell and Baron, 1990) followed by systemic approaches were adopted for this purpose. Recently vaccine uses are based on three enzymes (example, HyA, HyB and HyC). HyA is being used in its purified form (Pruett and Kunz, 1996) whereas; HyB and HyC are used in a variety of combinations (Colwell and Baron, 1990) (Table 3).

Initial trial using extracts of *Hypoderma* spp. larvae as candidate vaccine was attempted toward the development of a defined vaccine against cattle-grub infestations using the hypodermin A (one of the three enzymes which are secreted by the first instar larvae during its migration). The advantages of a vaccine over chemical control include less damage to the environment, complete and lifetime conversion of susceptible animals to resistant status, and use in animals such as dairy cattle for which systemic insecticide application is prohibited during lactation. The immunization with hypodermin A, associated with various adjuvants, could provide protective immunity for calves when challenged with natural grub infestation. However, these experimental vaccines have not been fully exploited

against naturally occurring populations of *Hypoderma* spp.

### Integrated management

The first attempt at integrated management of *Hypoderma* spp. resulted from the suggestion to adapt the sterile male-release technology that was initially developed for eradication of the screwworm from North America and Mexico. The results of a preliminary trial in Alberta, Canada were very promising, and consequently, the Joint US-Canada Cattle Grub Project was initiated in 1982. The chemical reduction phase proved to be very successful using readily available systemic insecticides combined with 100% producer cooperation. However, the sterile fly component was less successful because there was no efficient technique for large-scale in vitro rearing of *Hypoderma* spp.

### CONCLUSION

Hypodermosis poses a serious global threat for animal health and has a serious impact on economic loss. This menace has a worldwide distribution pattern and is prevalent in many countries. In many countries the disease is not explored yet and there is a dire need of research on hypodermosis in those countries. It is therefore imperative that timely diagnosis and effective control strategies be employed in order to limit the disease spread. We recommend enforcement of eradication and vaccination programs in developing countries for betterment of livestock sector.

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