

ORIGINAL ARTICLE**Effects of Curcumin on Lung Histopathology and Fungal Burden in a Mouse Model of Chronic Asthma and Oropharyngeal Candidiasis**

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Background and Aims. Oropharyngeal candidiasis (OPC) is one of the most common local side effects of current therapy in chronic asthma. New therapeutic options with fewer side effects and reverse chronic changes are needed. Curcumin, as a promising antiinflammatory and antifungal agent, could be a candidate of alternative therapy in asthma. This study aimed to determine the efficacy of orally administrated curcumin on lung histopathology, serum nitric oxide levels and fungal burden in a murine model of asthma and OPC.

Methods. Thirty five BALB/c mice were divided into five groups: I, II, III, IV (placebo) and V (control). All groups except the control were sensitized and challenged with ovalbumin. OPC model was established after the model of chronic asthma. Lung histology, serum nitric oxide levels and fungal burden were evaluated after 5 days of treatment with curcumin, dexamethasone, curcumin-dexamethasone combination and placebo. Evaluation of lung histology included subepithelial smooth muscle and epithelial thickness and number of goblet and mast cells by using light microscopy.

Results. All histological parameters improved in curcumin group similar to dexamethasone group. Curcumin and dexamethasone-curcumin combination were also as effective as dexamethasone on decreasing nitric oxide levels. Oral fungal burden was significantly lower in curcumin-treated group than dexamethasone.

Conclusions. In our study we demonstrated that curcumin administration alleviates the pathological changes in asthma and decreases the fungal burden. Curcumin may have a potential effect on treating chronic asthma and decreasing the frequency of the OPC. © 2011 IMSS. Published by Elsevier Inc.

Key Words: Chronic asthma, Mouse, Curcumin, Oropharyngeal candidiasis, *C. albicans* colonization.

Introduction

Asthma is a chronic inflammatory disease of the airways characterized by airway hyperresponsiveness to various stimuli, airflow obstruction and airway remodelling (1). It is the most common chronic disease in childhood, and prevalence, morbidity and mortality have increased in recent years (2). Cumulative prevalence of asthma ranges between 4 and 23% in industrialized countries and studies from our country also state that it varies from 13.7–15.3% (3,4).

Antigen-induced immunoglobulin (Ig) E production, airway inflammation and hyperresponsiveness are the principal factors in the pathogenesis of asthma. Much of the inflammation can be attributed to helper T-cell type 2 (Th2) cytokine activation. Activated Th2 cells induce asthma through the secretion of an array of cytokines that activate inflammatory pathways. Interleukin (IL)-4, IL-5 and IL-13 are elevated in the asthmatic lung and they are the central regulators of many features of disease (5). One of the other cytokines involved in the pathogenesis of asthma is the endogenous nitric oxide (NO) produced by inducible nitric oxide synthase (iNOS). NO is primarily produced in the lungs by the epithelial cells in the airways, endothelial cells of vessels and neurons (6). Once produced,

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it freely diffuses and enters target cells where it activates guanylate cyclase to produce cyclic guanosine monophosphate, which promotes smooth muscle contraction (6,7). NO plays a central role in endothelial dependent control of vascular tone, smooth muscle contraction and regulating airway blood flow in lungs. The role of altered NO homeostasis in asthma has been studied extensively. NO strongly promotes chemotaxis of inflammatory cells in the lung and favors the development of Th2 response. In asthmatics, production of NO is greatly increased due to induction of iNOS by pro-inflammatory cytokines leading to elevated levels of exhaled NO (8).

Current strategies for the management of asthma mainly focus on suppressing airway inflammation, and steroids are the most effective antiinflammatory drugs in asthma (9). Inhaled steroids are mainly used and currently the mainstay of asthma therapy because of the severe side effects of systemic steroids. Inhaled steroids also have several systemic and local side effects when used at high doses for a long time. Adrenal suppression, growth failure, disorders of bone metabolism, cataracts and glaucoma are the major systemic side effects, whereas oropharyngeal candidiasis (OPC), dysphonia, lingual hypertrophy and pharyngitis may be regarded as the most commonly seen local side effects (10,11). The frequency of OPC varies according to the type and the dosage of inhaled steroid used (12). Searching for the use of alternative and complementary treatments that have fewer side effects and reverse permanent changes in the lung are continuously increasing.

Chinese and Indian herbal preparations are one of the most commonly used alternative treatments in asthma (13). The medicinal use of *Curcuma longa* dates back to the time of Egyptian and Indian culture more than 6000 years ago. Curcumin, a yellow pigment obtained from the rhizome of *Curcuma longa*, is a member of the curcuminoid family of compounds and its antiinflammatory, antioxidant and antitumoral pharmacological activities have been reported (14,15). Curcumin has been investigated in animal models of allergy and reported as an effective antiallergic in type I and type IV in animal models of allergy (16). Curcumin has been shown to inhibit the production of inflammatory cytokines and generation of NO (14,17). Antifungal activity of curcumin was also assessed by experiments done with crude extracts of *Curcuma longa* and efficacy as an antifungal agent has been reported (18).

Sprague Dawley and Wistar rats are frequently used in models of OPC. Rats may be a commercial carrier of *C. albicans*, but it does not exist in oral flora of conventionally raised mice. Murine model of OPC seems more appropriate as the clinical and histological features of oral thrush are also similar to that in humans (19). BALB/c mice are the most convenient type for the study of chronic asthma and OPC because they are high responders to ovalbumin (20).

To our knowledge there is no study in the medical literature evaluating the efficacy of curcumin on chronic airway

changes of asthma. *In vitro* antifungal efficacy of curcumin was previously studied, but there are no reported data about the effects of curcumin on *Candida* colonization established in a murine model of OPC. The aim of the present study was, for the first time, to investigate the effects of curcumin on lung histopathology, serum NO levels and fungal burden in a murine model of asthma and OPC.

Materials and Methods

Experimental Animals

Thirty five conventionally raised, 6- to 8-week-old male BALB/c mice weighing 18–20 g were used for the study. They were maintained in experimental animal laboratory of Dokuz Eylul University and kept in hygienic macrolene cages and fed a standard laboratory diet ad libitum in air-conditioned rooms on a 12 h light/12 h dark cycle. All experiments were carried out according to the protocols approved by the local animal use and care committee (Dokuz Eylul University, 59/2009). The protocols complied with the standards in the *Guide for the Care and Use of Laboratory Animals*, prepared by the Institute of Laboratory Animal Resources and published by the National Academy Press, National Research Council, Commission of Life Sciences, Institute of Laboratory Animal Resources.

Sensitization and Inhalational Exposure

Mice were divided into five groups. Mice in the study groups except for the control group were sensitized on days 0 and 14 by intraperitoneal (i.p.) injections of 10 µg chicken egg albumin (ovalbumin, grade V, ≥98% pure; Sigma, St. Louis, MO) with alum as an adjuvant. Mice in study groups I, II, III, and IV were then challenged with an aerosol of 2.5% ovalbumin in saline for 30 min/day for 3 days of the week for 8 weeks beginning from the 21st day of the study. Mice in control group (group V) received normal saline with alum i.p. on days 0 and 14 of the experiment and aerosolized saline without alum for 30 min/day for 3 days of the week for 8 weeks beginning from the 21st day of the study (21). Exposures were carried out in a whole body inhalation exposure system. Temperature and relative humidity were maintained at 20–25°C and 40–60%, respectively. A solution of 2.5% ovalbumin in normal saline was aerosolised by delivery of compressed air to a sidestream jet nebulizer and injected into a chamber. The aerosol generated by this nebulizer comprised >80% particles with a diameter of <4 µm. Particle concentration was maintained in the range of 10–20 mg/mm³ (22).

Experimental Model of OPC and Study Drugs

After completion of the chronic asthma model, OPC model was established according to the methods described by Kamai et al. (23). Each mouse was examined for *Candida*

colonization by taking an oropharyngeal swab after establishment of the model of chronic asthma. *C. albicans* was plated on ATCC 9028 Sabouraud's Dextrose Agar (SDA) for 48 h at 35°C and a suspension was prepared from the colonies containing 2×10^8 blastospores/mL of sterile saline. Before inoculation, mice were anesthetized by i.p. injection with 200 mg/kg ketamin hydrochloride and 10 mg/kg xylazine. Next, 3 mm diameter sterile cotton wool balls were saturated with 100 µl of the suspension and then placed sublingually in the oral cavity of the mice in Groups I–IV for 2 h. A similar technique was used with sterile saline in the control group (Group V). On the fourth day after inoculation, oropharyngeal swabs were taken from each mouse, plated on SDA and incubated at 35°C for 48 h. The strains taken from mice were identified with germ tube test and the help of the morphological findings on CHROMagar Candida and Corn Meal Agar with Tween 80 medium. On the fifth day after inoculation, mice in group I received 1 mg/kg i.p. dexamethasone, group II received 200 mg/kg curcumin (Sigma) dissolved in 2% carboxymethyl cellulose (CMA) orally. Group III received both 1 mg/kg dexamethasone i.p. and 200 mg/kg curcumin orally, group IV received saline i.p. All study drugs were administered once a day for 5 days. Afterwards, oropharyngeal swabs were taken from mice in all groups and plated on SDA quantitatively for colony counting. Mice were then sacrificed by an overdose of ketamin.

Schematic presentation of experimental procedure and study drugs are presented in Figure 1.

Determination of NO

Serum samples were obtained after mice were sacrificed. NO levels in serum samples were measured by a Griess reaction. Nitrite is generated by the rapid oxidation of NO, and nitrite amount reflects the amount of NO produced. Briefly, 100 µl of serum samples were mixed with equal volumes of Griess reagent A (naphthyl ethylenediamine dihydrochloride, 0.15% mM) and Griess reagent B (1.5% mM sulfanilamide in o-phosphoric acid) in a 96-well microtiter plate. After 10 min of incubation at room temperature, absorbance at a wavelength of 540 nm was measured in a microplate reader (Reader model 230S, Organon Technica, Microwell system, Holland) (24).

Histopathological Analysis

Tissue specimens were obtained from tongue tissue and mid-zone of the left lungs of mice. Samples were fixed in 10% formalin for light microscopic evaluation. Two investigators who were blinded to the treatment groups interpreted the histopathology. After fixation, lung tissue samples were embedded in paraffin for light microscopic evaluation and serial sections of 5 µm thickness were taken. After choosing the first section randomly, 10 sections in

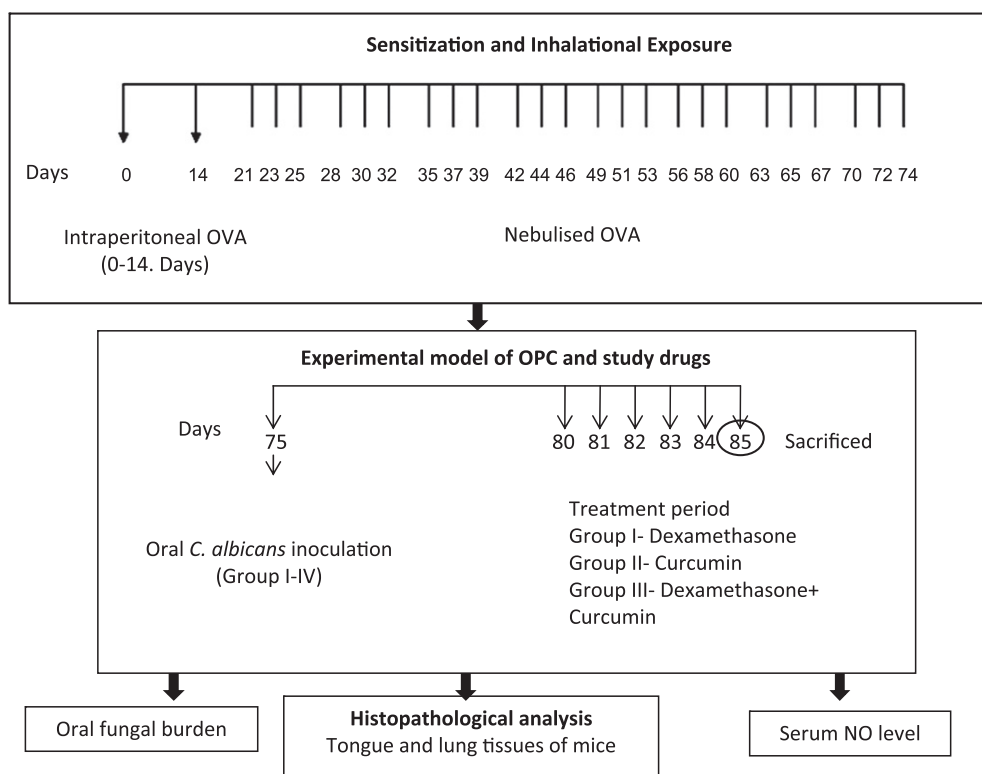


Figure 1. Schematic presentation of the experimental procedure and study drugs.

each mouse were selected by skipping over 10 sections and proceeded to the staining process. For light microscopic evaluation of lung tissues, three different staining processes were used. The first 10 samples were stained with hematoxylin and eosin (H&E). In these samples, general tissue features were examined and thicknesses of epithelium and subepithelial smooth muscle layers of the medium and small airways were measured. In order to evaluate the thicknesses of epithelium and subepithelial smooth muscle layers, measurements were performed from four points of each airway at levels of 3, 6, 9, and 12 o'clock. Considering that each section contained two to three airways, almost 20 or more airways were evaluated in each mouse.

The consecutive 10 sections were stained with toluidine blue and the other 10 sections with periodic acid–Schiff (PAS). Photomicrographs were taken randomly from five fields of each section that were stained with toluidine blue. For mast cell enumeration, a standard transparent counting frame representing an area of $16,400 \mu\text{m}^2$ was used manually and eight fields in each photograph were examined for each mouse. Goblet cells stained with PAS were enumerated in 10 sections of each mouse. In each section, three to five randomly selected airways were photographed. Circumferences of all airways were measured and goblet cell numbers in these areas were recorded. For standardization, goblet cell numbers in $100 \mu\text{m}$ were analyzed by division of total goblet cell number to the total length of airway circumferences and multiplying the result by 100.

For light microscopic examination of the tongue tissue, both H&E and PAS stains were used. *C. albicans* infection was assessed by evidence of lesions and by yeast colonization on the dorsal tongue detected using a digital imaging system. A semiquantitative scale from 0 to 3 was used based on the presence and severity of the tissue injury in the dorsal tongue sections as follows: 0, none; 1, slight; 2, mild; 3, severe. The atrophy of papillae, inflammation, abscess formation, congestion and yeast or hyphae formation were evaluated.

Photomicrographs were taken by JVC TK-890-E camera (Japan), which was adapted on Olympus BH-2 RFCA model microscope (Olympus Optical, Tokyo, Japan). Histological analysis was carried out with UTHSCSA Image Tool for Windows v. 3.00 software.

Statistical Analysis

SPSS 15.0 package program was used for the statistical analysis. Data were presented as mean $\pm$ standard deviation (SD) (minimum–maximum) of animals in each group. Comparisons between all groups were conducted by using one-way anova method. Post hoc-Bonferonni test was used for between group comparisons and Wilcoxon signed-rank test for the case of repeated measurements on a single sample. Results of the scores of tongue histopathological findings were presented as mean $\pm$ SD. Oral fungal burden before and after administration of study drugs was presented as mean $\pm$ SD. All data were analyzed by Kruskal-Wallis and Mann-Whitney test for dual comparisons; $p < 0.05$ was considered statistically significant.

Results

We compared the control group with the placebo in order to show that the asthma model was established. In the chronic asthma group (placebo), the number of mast cells, goblet cells and the subepithelial smooth muscle and epithelial thicknesses were significantly higher than the control group (Table 1). These results considered that the model was established.

Subepithelial smooth muscle and epithelial thickness and the number of mast cells and goblet cells in Group II (curcumin 200 mg/kg) were significantly lower than the placebo group. In Group I (dexamethasone 1 mg/kg) all parameters were also lower than the placebo group (Table 1).

Curcumin significantly improved subepithelial smooth muscle and epithelial thickness and number of mast and goblet cells similar to dexamethasone, the gold standard treatment of asthma (Table 1). Curcumin and dexamethasone combination demonstrated no superiority to dexamethasone alone in any parameters. Light microscopic findings of lung tissue and comparison of all groups can be seen in Figures 2–4.

Growth of *C. albicans* was determined from the oropharyngeal swab specimens plated on SDA in all study groups

Table 1. Comparison among study groups

	Dexamethasone 1 mg/kg	Curcumin 200 mg/kg	Dexamethasone Curcumin	Placebo	Control
	Group I mean $\pm$ SD	Group II mean $\pm$ SD	Group III mean $\pm$ SD	Group IV mean $\pm$ SD	Group V mean $\pm$ SD
Subepithelial smooth muscle thickness (μm)	7.09 $\pm$ 0.47 ^a	5.97 $\pm$ 0.45 ^{a,b}	6.30 $\pm$ 0.59 ^{a,b}	9.30 $\pm$ 0.59	5.34 $\pm$ 0.38
Epithelium thickness (μm)	14.86 $\pm$ 3.00 ^a	15.71 $\pm$ 2.90 ^{a,b}	16.40 $\pm$ 4.01 ^{a,b}	27.66 $\pm$ 14.15	12.67 $\pm$ 3.47
Numbers of mast cells/16400 (μm^2)	1.57 $\pm$ 0.65 ^a	1.25 $\pm$ 0.29 ^{a,b}	1.83 $\pm$ 0.60 ^{a,b}	3.00 $\pm$ 0.97	0.71 $\pm$ 0.29
Numbers of goblet cells/100 (μm)	0.89 $\pm$ 0.53 ^a	0.52 $\pm$ 0.32 ^{a,b}	0.60 $\pm$ 0.36 ^{a,b}	2.43 $\pm$ 0.62	0.30 $\pm$ 0.29

^a $p < 0.05$ in groups vs. placebo.

^b $p > 0.05$ in groups vs. dexamethasone.

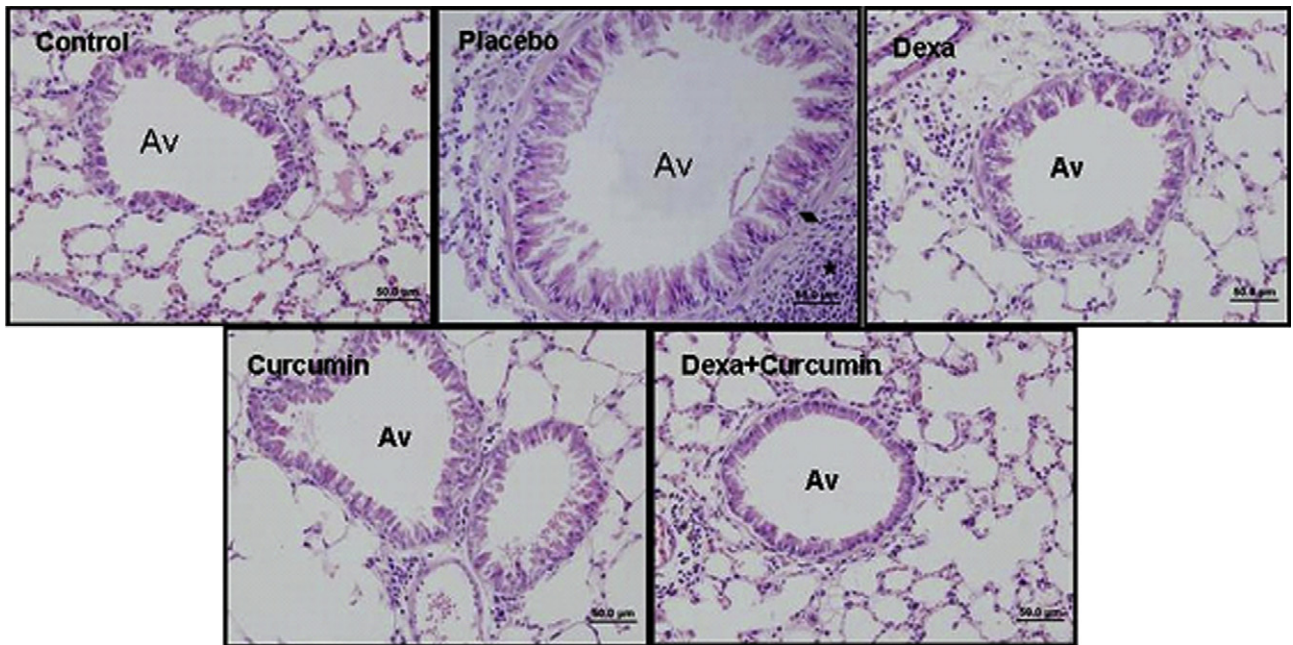


Figure 2. Airway sections of OVA-induced asthma mice by hematoxylin-eosin staining. Note the increased peribronchiolar mononuclear infiltration (*) and thickened subepithelial smooth muscle (arrow with two arrowheads) in OVA-induced asthma mice (placebo) compared to normal tissue (control). Av; Airway. Dexa; Dexamethasone. (A color figure can be found in the online version of this article.)

except Group V (Figure 1). Oral fungal burden was similar in all groups before administration of study groups ($p = 1$). Decrease in *Candida* colonization was significant among the groups after administration of study drugs ($p < 0.05$). When the colonization after the treatment period was compared, oral fungal burden was significantly lower in

curcumin-treated group than dexamethasone and similar to dexamethasone-curcumin combination ($p < 0.05$, $p = 1$).

Light microscopic findings of the tongue tissue are represented in Table 2 and Figure 5. All parameters of the *C. albicans* infection are less prominent in Group II compared to Group I ($p < 0.05$). Changes of oral fungal burden of

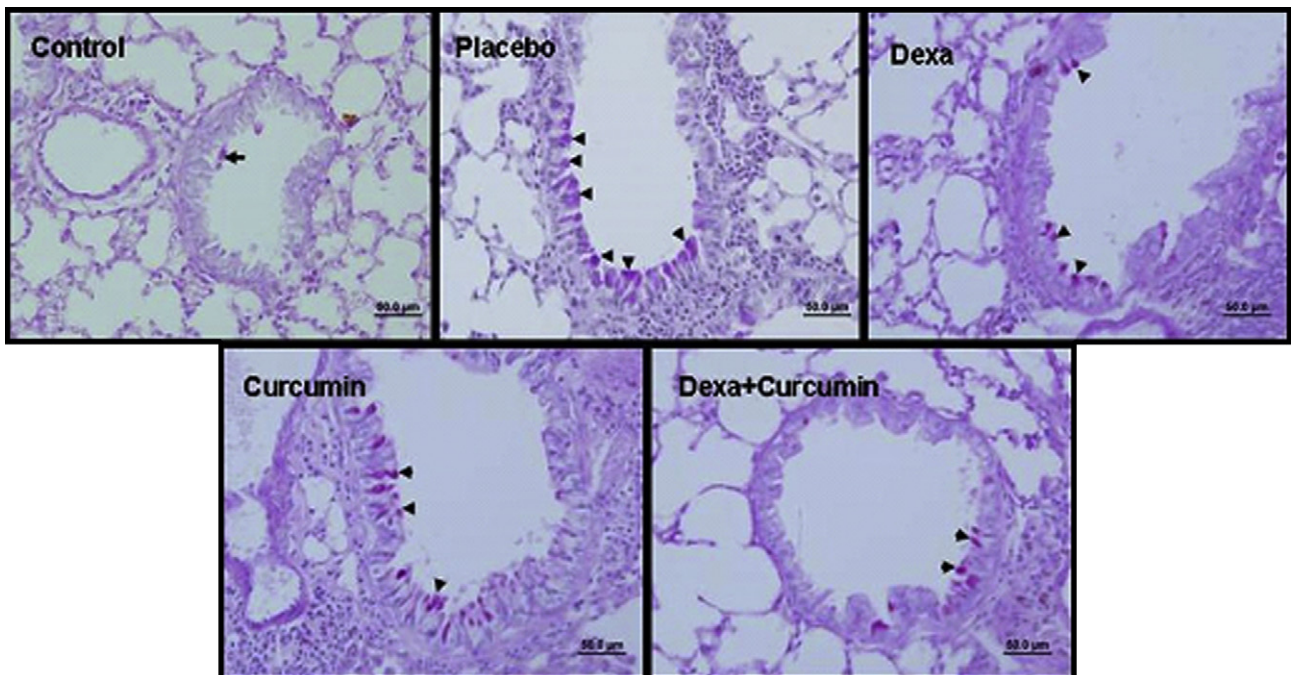


Figure 3. Airway sections of OVA-induced asthma mice by PAS-staining. Note the high numbers of goblet cells (arrows) in OVA-induced asthma mice (placebo) compared to normal tissue (control). Curcumin suppressed goblet cell hyperplasia in lung tissue. Dexa; Dexamethasone. (A color figure can be found in the online version of this article.)

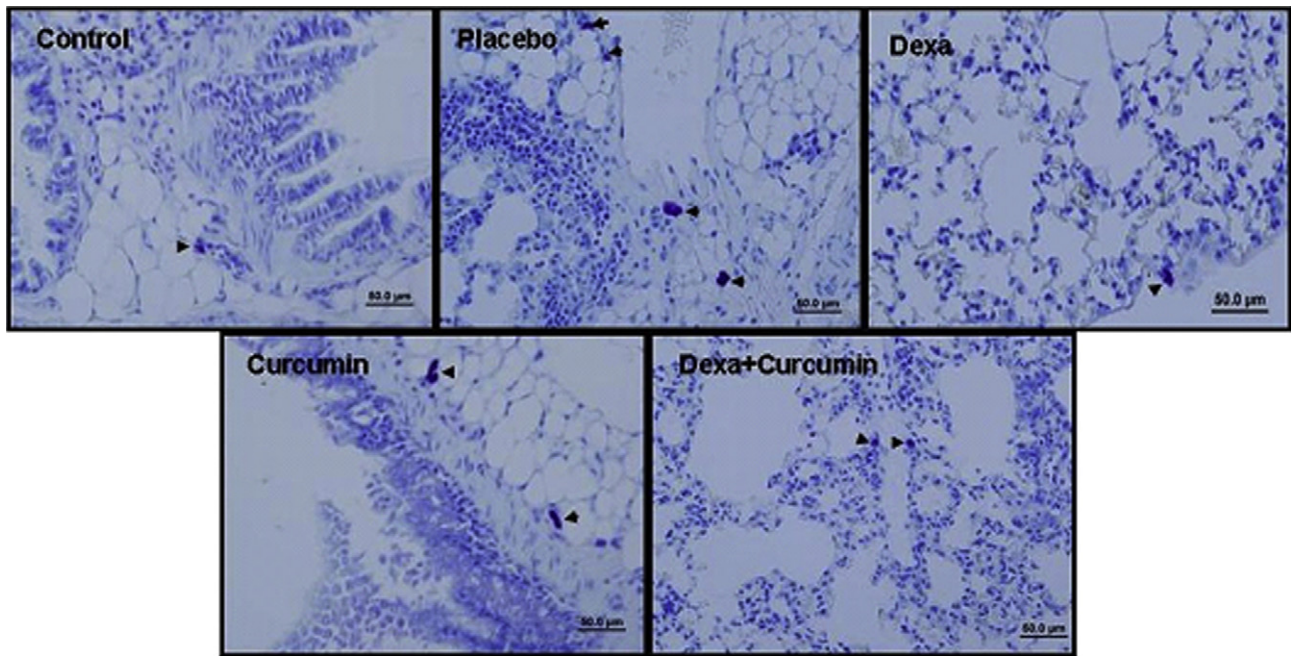


Figure 4. Airway sections of OVA-induced asthma mice by toluidine blue staining. Note the high numbers of mast cells (arrows) in OVA-induced asthma mice (placebo) compared to normal tissue (control). In groups dexa and curcumin; number of mast cells was significantly less than in OVA-induced asthma mice. Dexa: Dexamethasone. (A color figure can be found in the online version of this article.)

mice after administration of study drugs are shown in Figure 6.

NO levels were significantly lower in control group compared with placebo (Group IV) ($p < 0.05$). Group II and Group III were similar according to NO levels but both were significantly lower than the placebo group ($p = 0.96$, $p < 0.05$, $p < 0.05$ respectively). Curcumin and dexamethasone-curcumin combination were as effective as dexamethasone on decreasing NO levels. NO levels of study groups are shown in Figure 7.

Discussion

Herbal therapies of Chinese and Indian origin are known to be used in alternative therapy of asthma. Although the anti-inflammatory properties of curcumin have repeatedly been

reported, its effects on lung histopathology of asthma have not been evaluated. The objective of our study was to evaluate the effects of curcumin on lung histopathology and serum NO levels in an experimental model of chronic asthma. We also investigated the effects of curcumin on oral fungal burden in the murine model of OPC established after the model of chronic asthma.

The frequency of esophageal candidiasis due to inhaled corticosteroid use was reported to be 35% (25). This is much higher than the probability of OPC developing spontaneously. Thus, newer therapeutic modalities with fewer side effects and can reverse the permanent changes of the lung are needed. The use of complementary and alternative treatments in many diseases have been increasing in recent years. In a study involving a pediatric population, it was shown that alternative therapy modalities were used in 53% of the patients at least once and in 23% of the patients

Table 2. Severity scores of *C. albicans* infection of tongue tissue among the study groups

Groups	Inflammation mean $\pm$ SD	Congestion mean $\pm$ SD	Atrophy mean $\pm$ SD	Abscess formation mean $\pm$ SD	Yeast mean $\pm$ SD	Hyphae mean $\pm$ SD
Group I	2.14 $\pm$ 0.26 ^a	2.28 $\pm$ 0.18 ^a	2.57 $\pm$ 0.20 ^a	0 $\pm$ 0.0	2.42 $\pm$ 0.20 ^a	0 $\pm$ 0.0
Group II	1.14 $\pm$ 0.14 ^{a,b,c}	1.42 $\pm$ 0.20 ^{a,b,c}	1.57 $\pm$ 0.20 ^{a,b,c}	0 $\pm$ 0.0	1.57 $\pm$ 0.20 ^{a,b,c}	0 $\pm$ 0.0
Group III	1.42 $\pm$ 0.20 ^a	1.42 $\pm$ 0.20 ^{a,b,c}	1.85 $\pm$ 0.26 ^a	0 $\pm$ 0.0	1.57 $\pm$ 0.20 ^{a,b,c}	0 $\pm$ 0.0
Group IV	2 $\pm$ 0.21 ^a	2.42 $\pm$ 0.29 ^a	2.42 $\pm$ 0.20 ^a	0 $\pm$ 0.0	2.42 $\pm$ 0.20 ^a	0 $\pm$ 0.0
Group V	0 $\pm$ 0.0	0 $\pm$ 0.0	0 $\pm$ 0.0	0 $\pm$ 0.0	0 $\pm$ 0.0	0 $\pm$ 0.0

^a $p < 0.05$ in groups vs. control (Group V).

^b $p < 0.05$ in groups vs. placebo (Group IV).

^c $p < 0.05$ in groups vs. Group 1.

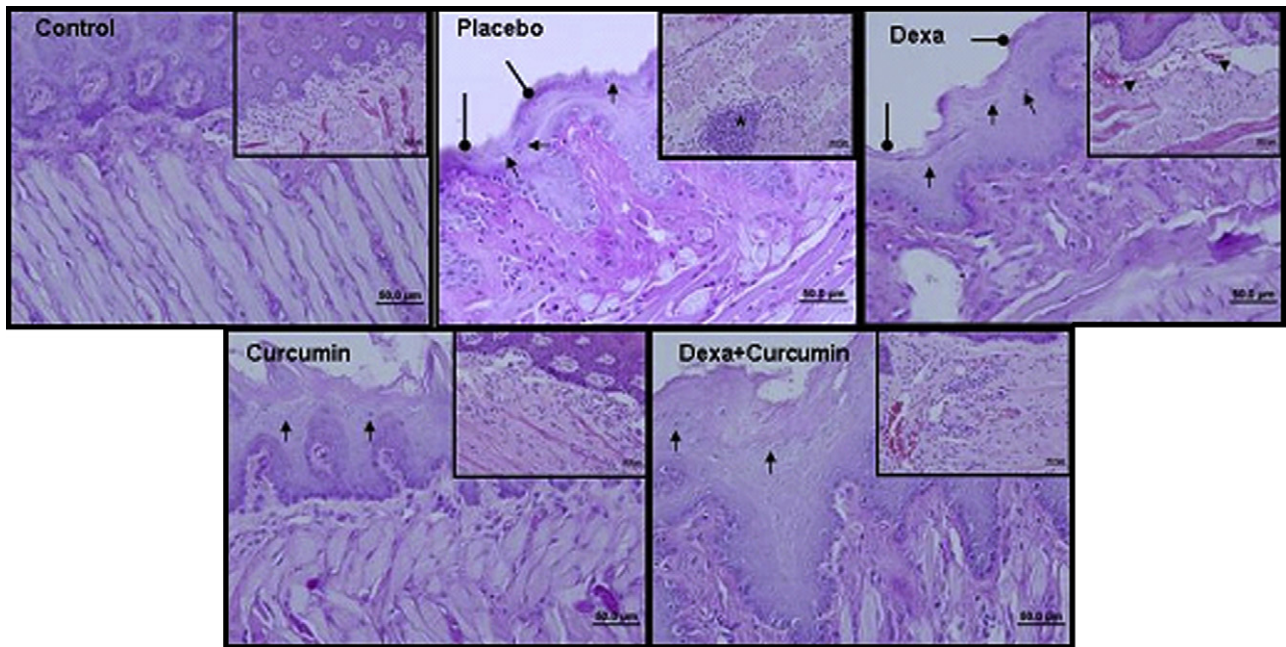


Figure 5. Light microscopic findings of dorsal tongue of mice. In representative histological images, tongue tissues were stained with PAS and H&E (insets). Tongue section from placebo and dexamethasone treated mice, showing atrophy of the papillae (arrows with roundhead), mononuclear inflammatory infiltration (*), and congestion (arrowheads). Tissue lesions were significantly less with curcumin treatment. Arrows; yeast formation. Dexa: Dexamethasone. (A color figure can be found in the online version of this article.)

during recent months. Herbal remedies were the most common of the alternative therapy modalities and asthma patients were the most common patient group using these remedies (26). There is another report showing that 60% of patients with persistent asthma and 70% of patients with severe asthma use alternative therapy modalities. Herbal remedies were the third most commonly used of these modalities in a previous study (27). A study from our country also stated that 49% of children with asthma used any modality of alternative therapy and herbal preparations were the second most commonly used alternative (31%)

(28). We used curcumin, an active compound of *Curcuma longa*, as an alternative therapy modality in our study.

The anti-asthmatic property of curcumin has been tested in several studies. In the study of Ram et al. (29), curcumin was tested in a guinea pig model of airway hyperresponsiveness. The authors concluded that curcumin treatment significantly inhibits the OVA-induced airway constriction and airway hyperactivity. Curcumin was also found to have an effect on controlling allergic diseases through inhibiting the production of cytokines affecting eosinophil function and IgE synthesis (30). It has been shown that curcumin inhibited

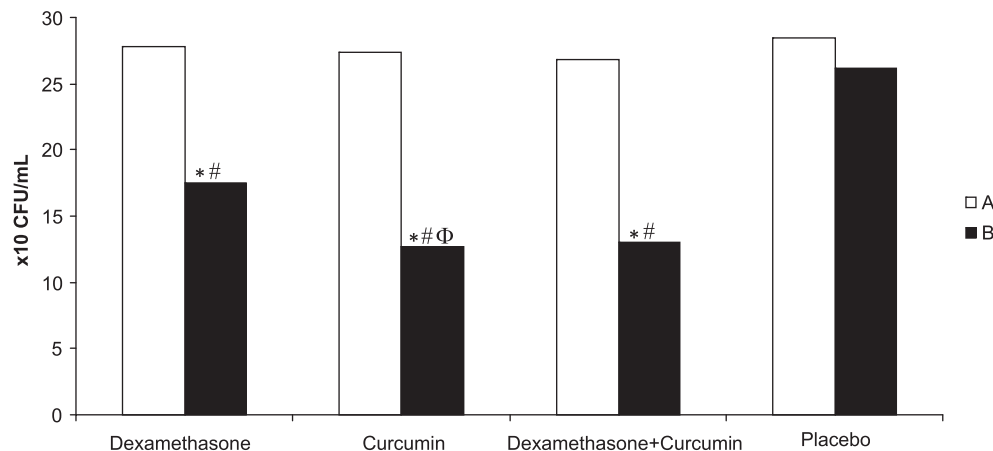


Figure 6. Oral fungal burden of mice before and after administration of study drugs. (A) Before administration of study drugs. (B) After administration of study drugs. * $p < 0.05$ compared with before administration of study drugs; # $p < 0.05$ compared with the placebo group; Φ $p < 0.05$ compared with the dexamethasone group.

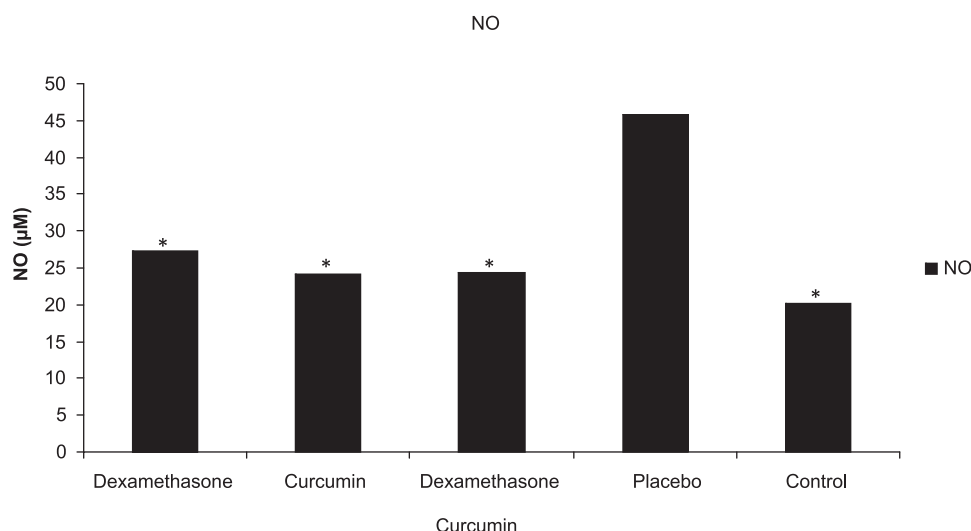


Figure 7. NO levels of study groups. * $p < 0.05$ compared with the placebo group.

the proliferative response of lymphocytes and the production of IL-2, IL-4, IL-5 and GM-CSF by allergen-stimulated lymphocytes. Moon et al. (31) also concluded that curcumin attenuated OVA-induced asthmatic inflammation in mice accompanied by the suppression of iNOS and NO expression and regulated the Th1/Th2 balance to suppress inflammation. In a current study, although the cytokine profiles of the experimental animals were not evaluated, it was shown that curcumin significantly ameliorated the structural changes of asthma.

The fact that NO levels are increased in the exhaled breath condensate of patients with asthma serves as a noninvasive means of inflammation in asthmatic airways (32). Increased exhaled NO in asthmatics was reported to be due to release of NOS II enzyme in the airways and normalization of NO levels was demonstrated after steroid therapy (33). Moon et al. (31) demonstrated that production of inducible NO in lung tissue resulted after OVA challenge of mice were inhibited by pretreatment of mice with curcumin. Supplementation with curcumin in human epithelial cells decreased iNOS and NO production induced by IFN- γ . In our study we could not investigate the NO levels in exhaled breath but results of NO in serum also indicated that curcumin and dexamethasone-curcumin combination were as effective as dexamethasone on decreasing NO levels. It may be hypothesized that alterations of NO levels may lie behind the antiasthmatic effect of curcumin in our study.

Antifungal properties of *Curcuma longa* have been reported in the literature. Turmeric oil extracted from *Curcuma longa* was reported to have antifungal properties against *Aspergillus flavus*, *A. parasiticus*, *Fusarium moniliforme* and *Penicillium digitatum* (18). In addition to the reported *in vitro* antifungal property of curcumin, we investigated its *in vivo* efficacy on *C. albicans* in the experimental model of OPC. We observed significantly better scores of *C. albicans* infection in curcumin-treated group. Histopathological

findings also supported these observations. We concluded that curcumin itself and also in combination with dexamethasone resulted in a decrease in *Candida* colonization more than dexamethasone. We also observed a significant decrease in Group I in which the study drug was only dexamethasone. This result could raise a question about how dexamethasone use did not result in an increase in *Candida* colonization. In general, an increase may be expected because of the immunosuppressive nature of steroids. But frequency of OPC varies greatly according to dosage, type of steroids and also the length of therapy. It may be speculated that 5 days of systemic steroid therapy may be the reason for this result. Outcome in placebo group showed that study drugs had a beneficial effect on *Candida* colonization and colonization was significantly decreased in the groups treated with curcumin when compared to dexamethasone.

Local side effects of steroid therapy are not an important cause of morbidity but because they affect the adherence to therapy, asthma control could not be maintained. Results of this study showed that oral administration of curcumin alone or in combination with dexamethasone reversed the established chronic changes of lungs in a mouse model of chronic asthma. Additionally, it was also shown to decrease the fungal burden in an experimental model of OPC. Curcumin, a promising antiinflammatory and antifungal agent, may be used as an alternative or adjunct to steroid therapy in asthma. Optimal dosage, route of administration and duration of treatment need to be elucidated with future studies before curcumin can be accepted and incorporated into clinical medical practice.

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