



Frequency of goose and duck down causation of hypersensitivity pneumonitis within an 80-patient cohort



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ABSTRACT

Background: A variety of antigens have been identified as causative of hypersensitivity pneumonitis (HP), which is characterized by inflammation to the lung parenchyma that is induced by exposure. Goose and duck down (GDD) bedding is often overlooked by physicians as a potential cause, yet the use of GDD has markedly increased in recent years, paralleling an increased frequency of reports of GDD-induced HP.

Objective: To determine the frequency of GDD as the causative antigen in patients with HP who use bedding that contains GDD.

Methods: Patients referred with a working diagnosis of HP underwent a detailed environmental history. Those who were using GDD were asked to remove it as an avoidance procedure. Signs, symptoms, spirometry, and inflammatory markers were followed up at weekly intervals for up to 1 month to determine the effect of remediation.

Results: Eighty patients with HP were seen during an 8-year period. Thirty-two patients (40%) were using GDD bedding. Of these 32 patients, 12 (37.5% of those exposed and 15% of the total HP population experienced remission (or nonprogression) of disease by simply avoiding GDD bedding. Eleven (92%) of these 12 patients were female. In patients with GDD-induced HP, lung biopsy patterns were varied.

Conclusion: Approximately one-third of patients with HP, who slept with GDD, had persistent improvement or remission with simple avoidance. The higher incidence of GDD-induced HP in females may be hormonal and/or sociocultural related. Lung biopsy findings were across the spectrum of histopathologic patterns. Avoidance-challenge techniques were effective in confirming diagnoses and causation and mitigating the need for additional remediation.

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Introduction

Hypersensitivity pneumonitis (HP) is an immunologically mediated lung disorder caused by inhalation of antigens stimulating primarily a lymphocytic inflammation in the peripheral airways and interstitial tissue. Causative antigens have been historically recognized in occupational settings.¹ However, as more safety measures have been initiated to reduce exposure in the workplace, the home has become the primary causative environment.^{1–7} The home is a complex environment influenced by

geographic location, architectural design, and contents and lifestyles of the inhabitants. Because the primary long-term management of this disorder is avoidance of the causative antigen(s), a thorough environmental history² should quickly rule out most of the recognized occupational causes.¹

With elimination of the workplace environment, evaluation should then center on the home, in which the most frequent causes of HP are avian antigens, contaminated humidifiers and air conditioning systems, and heavy concentrations of indoor mold.^{1–7} When the causative antigen is uncertain, an air-quality hygienist is often called on to determine a probable cause and make recommendations for potentially costly remediation. In an attempt to decrease the cost of the medical evaluation, as well as mitigate the need for investigation and remediation of the home, we describe a series of patients in whom a thorough environmental history and an

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avoidance technique resulted in a rapid confirmation of diagnosis, identification of the causative agent, clinical improvement, and an effective, inexpensive remediation.

Methods

An ongoing study⁷ of patients with histories of respiratory tract signs and symptoms, seemingly associated with a contaminated environment, was altered in 2006 and continued through 2013 to determine the frequency of goose and duck down (GDD) bedding use and its causative role in a cohort of patients referred with suspected HP. There were many patients referred who were later diagnosed with another disorder: 2 patients with allergic bronchopulmonary mycosis, 1 patient with severe chronic obstructive pulmonary disease and hypereosinophilia, 3 patients with autoimmune interstitial lung disease, and 5 patients mold-induced asthma in mold contaminated homes. There were several cases of chronic cough with mixed, obstructive or restrictive pulmonary functions and severe asthma or chronic obstructive pulmonary disease that did not meet sufficient criteria to be considered.

Eighty patients were referred by pulmonologists when the history, physical examination, pattern of presentation, pulmonary function tests, computed tomography (CT) of the chest, and, in some cases, a lung biopsy specimen were suggestive of a diagnosis of HP (Table 1). Patients were further evaluated with a detailed environmental history,³ skin prick testing (in some cases, to common aeroallergens), and blood work, including a complete blood cell count, sedimentation rate, C-reactive protein, and immunoglobulin measurement. Serum precipitins were assessed to *Aspergillus fumigatus* 1, *A. fumigatus* 6, *Aspergillus pullulans*, pigeon serum, *Micropolyspora faeni*, *Thymus vulgaris*, *Aspergillus flavus*, *A. fumigatus* 2, *A. fumigatus* 3, *Setaria viridis*, *Thermoactinomyces candidus*, and *Thermoactinomyces sacchari* (Table 2). On the basis of the environmental history, an investigation of the home or workplace was undertaken by one of the authors (R.L.J.) or, if GDD was present in the environment, a removal and avoidance plan was executed. In those patients in whom remission or nonprogression was not achieved by avoidance of GDD, a formal investigation was initiated.³ The initial evaluation was a smell test, by someone who would only occasionally enter the environment, to detect any unusual odor. A visual test was performed to detect dark dust exiting air conditioning (A/C) vents onto the ceilings or growths of mold around areas of potential moisture within the home from roof leaks or plumbing problems. Carpets were rolled back to examine the carpet pads and underflooring in areas where animals had

urinated or excessive moisture had occurred. Swabs for cultures of these suspicious areas were obtained. Humidity was measured within the home when closed. Gravity air cultures were obtained throughout the home.

If this initial effort did not reveal a probable cause, one of the authors (R.L.J.) personally conducted an investigation. A moisture meter was used to detect moisture underneath carpets and inside wall spaces for clues of undetected moisture accumulation. If moisture was found, these carpets were rolled back and walls were entered to determine whether contaminations existed in these areas. An Andersen sampler was used for a formal culturing of the air inside the home. The A/C systems were opened at the plenum level to examine the A/C ducting above the A/C system (where contaminations usually exist). If this approach failed, the patients was asked to move to another location for 2 to 4 weeks to determine the effects on signs, symptoms, inflammatory markers, pulmonary function tests, and chest radiographs.

Natural Avoidance Challenge Plan

If GDD was being used in bedding materials, the patient was asked to remove and secure those materials (not destroy) in airtight plastic bags without any other investigation of the home environment. If the patient was taking systemic steroids, that medication was tapered and discontinued. The patient was then followed up to determine any return of symptoms or worsening of inflammatory markers and/or pulmonary function tests. If symptoms, inflammatory markers, or changes in spirometry recurred within a month after discontinuing use of steroids, a detailed investigation of the suspected environment was initiated. If systemic steroids had not been used, the patient was followed up to determine whether remission (return to normal) or nonprogression (stabilization of signs, symptoms, chest CT, and pulmonary functions) had been achieved by simple avoidance. For the untreated patients, if no improvement was documented within 1 month or the disease had progressed, GDD exposure was considered an unlikely causative factor and an environmental investigation was initiated. If the patient showed improvement, avoidance of GDD was continued. After 3 months of remission or nonprogression, the patient was offered the reuse of the causative GDD bedding as an active challenge or continued avoidance of the GDD (Fig 1).

Featured Case

An otherwise healthy, 64 year-old woman who was a nonsmoker presented with symptoms of shortness of breath, chest pain,

Table 1
Factors Suggestive of Hypersensitivity Pneumonitis

Stage	History	Radiologic	Laboratory	Pulmonary function
Acute	Acute onset, often intense, dyspnea, cough, 30% wheeze, extreme fatigue, fever common. May have musty odor, caged birds, GDD bedding in home.	Interstitial pattern, ground-glass opacities.	Often elevated WBC count, sedimentation rate, C-reactive protein level. Commercial serum precipitin test results often negative.	Restrictive pattern with decreased FVC, TLC, and DLCO. May have minimal response to inhaled bronchodilators.
Subacute	Moderate onset, less intense, dyspnea, cough, occasional wheeze, fever uncommon, weight loss. May have musty odor, caged birds, GDD bedding in home.	Interstitial pattern, ground-glass opacities, mild to moderate fibrosis.	May have elevated WBC count, sedimentation rate, C-reactive protein level. May have elevated serum immunoglobulins. Commercial serum precipitin test results often negative.	May have obstructive-restrictive pattern with decreased FVC, TLC, and DLCO. May have minimal response to inhaled bronchodilators.
Chronic	Gradual onset, low intensity, dyspnea, cough, no fever, weight loss. May have musty odor, caged birds, GDD bedding in home.	Advanced fibrosis, honeycombing, air trapping.	Normal WBC count, sedimentation rate, C-reactive protein level. May have elevated serum immunoglobulin levels. Commercial serum precipitin test results often negative.	May have obstructive-restrictive pattern with decreased FVC, TLC, and DLCO. No response to inhaled bronchodilators.

Abbreviations: DLCO, carbon dioxide diffusing capacity; GDD, goose and duck down; FVC, forced vital capacity; TLC, total lung capacity; WBC, white blood cell.

Table 2
Laboratory Data

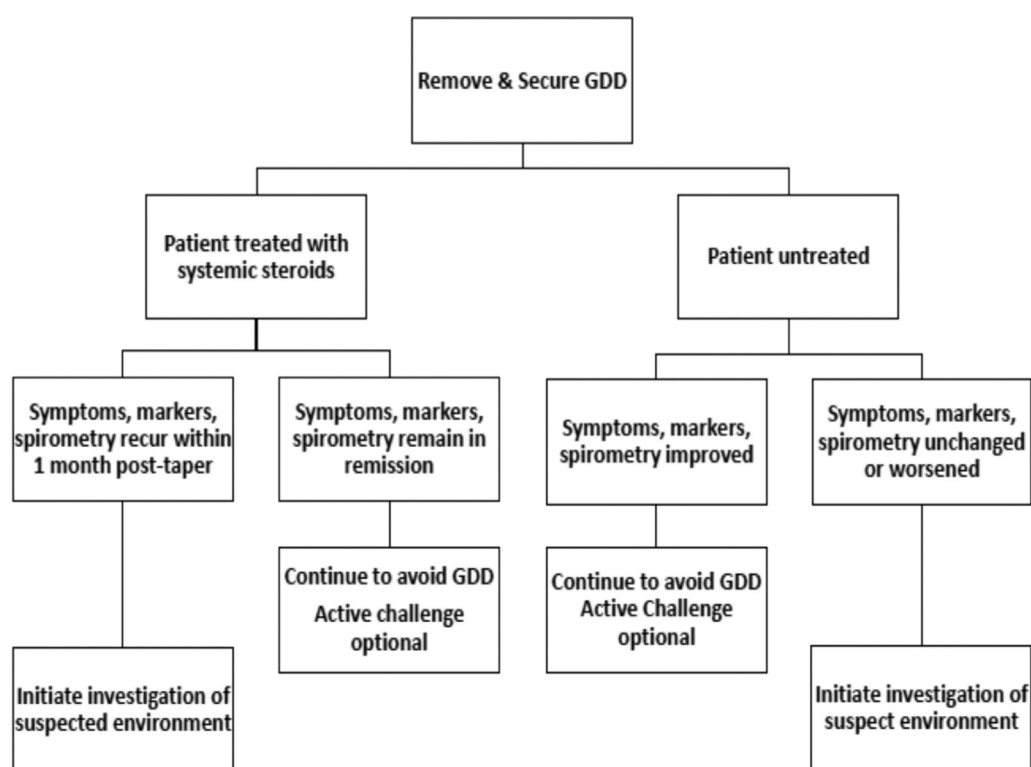
Patient No.	SPT result	WBC count, / μ L	Sedimentation rate, mm/h	CRP level, mg/dL	IgE, mg/dL	IgA, mg/dL	IgG, mg/dL	IgM, mg/dL	Precipitins and/or sslgG
1	ND	ND	2	0.26	ND	187	1000	89	Negative to all
2	Negative	6500	6	≤ 0.5	24.5	ND	ND	ND	Negative to all
3	Negative	6000	8	≤ 0.5	1.5	395	1673	315	Negative to all
4	Negative	16000	36	2.8	195	320	1330	149	Negative to all
5	Negative	9800	9	3.1	203	555	887	164	Negative to all
6	ND	13100	47	4.2	55	287	928	97	Negative to all
7	ND	8800	6	≤ 0.5	2	195	948	37	Negative to pigeon and positive to <i>Aspergillus flavus</i>
8	ND	6600	31	≤ 0.5	10	640	1112	78	Negative to all
9	ND	10000	22	1.2	1.5	27	1184	78	Negative to all
10	Negative	8500	29	0.8	24	228	1075	89	Pigeon positive to sslgG Positive to <i>Aspergillus niger</i>
11	ND	8900	54	1.6	260	413	1120	70	Pigeon positive to sslgG
12	Negative	ND	27	ND	79	124	2096	64	Pigeon positive to precipitins

Abbreviations: CRP, C-reactive protein; ND, not done; SPT, skin prick test; sslgG, serum specific IgG; WBC, white blood cell.

extreme fatigue, fever with chills, and decreased appetite with a 5-lb weight loss during the prior 48 hours. A physical examination revealed bilateral crackles in both lung bases and a temperature of 99.2°F. The results of chest radiography were normal; however, CT of the chest revealed mild, patchy infiltrates in both lower lobes. She was treated with a 7-day course of levofloxacin, 750 mg/d, and appeared to improve. Within another 10 days, her condition had worsened with more severe symptoms leading to hospitalization. Temperature was 102°F and oxygen saturation was 85% on room air. Bilateral rales were noted in both lung bases. The chest radiogram revealed a progressive bilateral interstitial pneumonia. A white blood cell (WBC) count was 13,100/ μ L, and the sedimentation rate was 47 mm/h. She underwent fiber optic bronchoscopy with a transbronchial biopsy interpreted as cellular nonspecific interstitial pneumonia (cNSIP) without evidence of granulomas. Initiation of treatment with systemic steroids resulted in remission of signs and

symptoms and resolution of infiltrates on chest radiography. She was seen by an allergist-immunologist (R.L.J.) who obtained an in-depth environmental history. She was not employed outside the home. No significant clues of causation were discerned other than the use of GDD bedding materials. She was advised to remove and secure down-containing bedding as she was tapered off systemic steroids. She remained asymptomatic, while not taking steroids, for approximately 1 month. While on a cruise ship, she slept for 2 nights on a down pillow and an exacerbation occurred. These symptoms, similar to her initial presentation, led to the removal of the down pillows and subsequent resolution of symptoms.

She remained stable for approximately 5 more months before another exacerbation occurred when she had traveled to a second home where there was furniture and decorative pillows that contained down material. Respiratory symptoms and fatigue were similar, but she did not have the associated fever and chills. Chest

**Figure 1.** Natural avoidance challenge technique for goose and duck down (GDD).

CT revealed multifocal, patchy, ground-glass bilateral infiltrates. A WBC count was 10,000/ μ L with a sedimentation rate of 27 mm/h and a C-reactive protein level of 4.2 mg/dL. Without specific treatment, signs and symptoms once again resolved with avoidance of GDD.

She remained stable and symptom free for another 6.5 years before sleeping in a hotel on down pillows for 4 nights. She recognized the onset of symptoms, like those previously experienced, and was seen by her primary care physician. The physical examination findings were normal; however, the WBC count was 15,200/ μ L and the sedimentation rate was 22 mm/h. Neither spirometry nor chest radiography was performed. Symptoms quickly resolved. She has remained free of symptoms for the past 2 years. Current pulmonary function reveals a forced expiratory volume of 117% predicted and a diffusing capacity of lung for carbon monoxide (D_{lco}) of 96% predicted.

Results

Eighty patients with suspected HP were evaluated between 2006 and 2013. The initial environmental history determined that 32 (40%) of 80 patients with HP were using GDD bedding. Of the 32 patients using GDD, 24 (75%) were female and 8 were male. Twelve (37.5%) of 32 experienced remission or nonprogression of disease by simply avoiding GDD bedding (Table 3). Overall, of the 80 patients seen with HP, 12 developed HP with GDD as the primary cause, an incidence of 15%. Laboratory data (Table 2) were unimpressive. Two patients had serum precipitins to common species of *Aspergillus*, which were not playing a causative role because signs and symptoms resolved on avoidance of GDD.

Inadvertent Challenges

No direct challenges were performed in this study because none of the 12 patients elected to reuse the GDD bedding to confirm the diagnosis and cause. Three patients, however, inadvertently exposed themselves to GDD bedding by failing to notify places where they lodged to remove GDD from their rooms (Table 4). The featured patient experienced 3 exacerbations, either in hotels or cruise ships, by failing to notify the staff of the GDD problem. A second patient slept on a GDD pillow in a hotel after being in remission for 1 year, which led to an exacerbation of symptoms, including fever and chills. Symptoms resolved spontaneously within 48 hours. The third patient has had exposure to GDD pillows on 2 occasions during the past 6 years when staying in hotels. On both occasions, she noted the onset of cough and extreme fatigue like her original presentation. Symptoms resolved on removing the GDD pillows. An additional patient, while avoiding GDD, noted exacerbation of symptoms on exposure to caged birds on 2 occasions. Symptoms resolved spontaneously on avoidance of the birds.

Biopsy Results

Nine of 12 patients underwent a transbronchial or open/thorascopic lung biopsy with varied histopathologic patterns (Table 4). Biopsy patterns included 5 having granuloma, 2 having a cNSIP pattern, 1 having an eosinophilic pneumonitis pattern, and 1 having inadequate tissue for interpretation. Bronchiolitis obliterans

organizing pneumonia (BOOP) was associated with 1 with granulomata and 1 with the cNSIP pattern.

Pulmonary Function Testing

All 12 patients underwent preavoidance pulmonary function testing, and 11 had a restrictive pattern. None had meaningful airway obstruction. Ten of the 12 had testing of diffusing capacity, and 9 of those 10 had clinically important reductions of D_{lco} (Table 5).

Other Causes

The remaining 64 cases of HP had a variety of causes (Table 6). Cases often arise in the clinical setting, where it is nearly impossible to determine the causative factor of the condition. In this study, we saw 4 additional patients who were highly suspected of having GDD-caused HP; however, the causative antigen could not be confidently identified. Two of these 4 patients required lung transplants before it was possible to determine GDD as the causative factor; one began to avoid GDD at the same time an air quality hygienist investigated and remediated a minor mold problem (rendering the GDD avoidance procedure uninterpretable), and one died of probable cardiovascular causes within 1 year. Twenty-six cases of HP were induced by microbial contamination of the home by excessive moisture from roof leaks, plumbing problems, and outside water from flooding, among other causes. Birds in the home, without GDD bedding, were identified as causative in 11 cases. Contaminated A/C system(s) (8 cases), contaminated workplaces, (7 cases), woodworking (1 case), contaminated vaporizer (1 case), and a mold contamination of an automobile A/C system (1 case) were the remaining recognized causes. There were 9 cases in which a cause, or causative environment, could not be determined. Three of these 9 cases were nonprogressive, and those 3 patients had moved from homes in other cities before coming to South Texas. Of the remaining 6 cases, no occupational causes could be implicated, and environmental histories and investigations of their homes failed to reveal a possible cause.

Discussion

In the South Texas area, there are no industries or occupations that are recognized to cause HP in workers.⁷ Therefore, almost all cases are caused by home-related exposures; mold contamination in either the structure or the A/C system, birds in the home, and GDD bedding. The use of GDD in bedding, including pillows, duvets, comforters, decorative pillows, articles of clothing, and stuffed furniture has markedly increased in recent years. This use of GDD is worldwide but appears to be more concentrated in Europe and East Asia. Most of the down is imported from Europe or China,⁸ where geese and ducks are raised extensively for food and commercial purposes.

This report covers an 8-year period, 2006 to 2013, during which a systematic approach was taken, so that if down bedding was used, an avoidance plan was initiated before launching a more extensive environmental investigation. This is the first study to observe the frequency of use of GDD by patients with HP and the frequency of causation in patients with HP by GDD within the United States. Previous reports of HP caused by GDD have been almost exclusively from Europe or Japan.^{9–21} Only a single case occurring within the United States has been previously reported.⁵

Eighty patients with a suggestive diagnosis of HP were seen by one of the authors (R.L.J.) during this 8-year period. Of these 80 patients, 32 (40%) reported a history of use of GDD in bedding. Twenty-four (75%) of the 32 patients sleeping on GDD were female. All removed and secured the GDD from the bed and were followed up to determine whether remission or lack of progression was achieved. Most of these patients had recent onset of findings with

Table 3
Causative Factors by Sex

Causative factor	No. (%) of patients		
	Total (N = 80)	Female (n = 57)	Male (n = 23)
GDD	12	11 (91.6)	1 (8.4)
Other	68	46 (67.6)	22 (32.4)

Abbreviation: GDD, goose and duck down.

Table 4
Clinical Findings^a

Patient No.	Age, y	Sex	Chest CT findings	Biopsy findings	Comments	Remission duration, y
1	59	M	Bilateral ground-glass opacities	HP with granuloma (open)	Inadvertent challenge positive at 1 y	8
2	69	F	Interstitial fibrosis, ground-glass alveolar infiltrates in RML and lingular of left lung	Inadequate (TB)		8
3	56	F	Bilateral ground-glass opacities in lung bases	HP with granuloma (TB)	Inadvertent challenges positive at 4 and 5 y	8
4	75	F	Bilateral apical, RML, and LLL infiltrates	ND		5
5	59	F	Peripheral nodular consolidation in RLL and LLL infiltrates	Eosinophilic (TB) pneumonitis		8.5
6	64	F	Multifocal nodular consolidation in RLL and LLL	cNSIP pattern (TB)	Inadvertent challenges positive at 2 and 7 mo and 7 y	9
7	64	F	Patchy ground-glass infiltrates bilaterally	HP with granuloma (open)		4.5
8	82	F	Reticular interstitial fibrotic changes	ND		8 (now deceased)
9	62	F	Ground-glass opacities bilaterally	HP with granuloma (open)		7.5 (now deceased)
10	58	F	Poorly defined nodular opacities bilaterally.	BOOP cNSIP pattern (TB)		lost to follow-up
11	73	F	Ground-glass opacities bilaterally	ND		8
12	56	F	Diffuse ground-glass opacities	HP with granuloma (open)	Inadvertent challenge to caged birds positive on 2 occasions at 4 and 6 y	10

Abbreviations: BOOP, bronchiolitis obliterans organizing pneumonia; cNSIP, cellular nonspecific interstitial pneumonia; CT, computed tomography; HP, hypersensitivity pneumonitis; LLL, left lower lobe; open, open biopsy; RLL, right lower lobe; RML, right middle lobe; TB, transbronchial.

^aThis table provides the information gathered from the clinical procedures performed on the 12 patients with goose and duck down–induced HP.

varying intensity of symptoms and inflammation. Of the 32 patients using GDD, 12 (37.5%) achieved remission or nonprogression that has been sustained for a period of 4 to 10 years (Table 4). Morell et al⁶ performed a similar 6-year study of patients diagnosed with idiopathic pulmonary fibrosis, in which 20 (43%) of 46 were found to have chronic HP after intense scrutiny of their environment. The most frequently recognized causes in that study were GDD bedding and mold in the home. Of the 20 cases of chronic HP in that cohort, 16 (80%) used feather bedding, with 10 (63%) having feathers as a primary cause.

In our population, 11 of 12 patients with GDD-induced HP were female. However, of the 32 patients sleeping on GDD, 24 were female and 11 (46%) had GDD as the primary causative antigen. Only 8 male patients slept on GDD, with 1 (12.5%) developing HP with GDD as the cause. On reviewing 30 published cases in which sex can be determined, 25 (83%) were female. Although many of these reports are single cases, Koschel et al⁹ reported 13 cases of feather duvet lung all occurring in female patients, and Inase et al¹³ reported 7 cases with 4 occurring in female patients. The sex of the

10 patients with feather bedding–induced HP reported by Morell et al⁶ was not identified, although of the 20 patients with chronic HP, 15 were male. Because the home has become the dominant causative environment, female patients have become the more dominantly affected. Jacobs et al⁷ reported 78.3% of patients were women in consecutive cases of organic antigen–induced interstitial lung disease. Hanak et al⁵ reported that 62% of 85 consecutive cases of HP were women. Morell et al²² reported that 75.5% of 86 patients with bird fancier's lung were women. There is evidence that women may be at an increased risk of developing certain lung disorders more so than men, possibly related to sex hormones²³ and sociocultural factors.²⁴

Biopsy specimens of the lung, transbronchial or open, may show varied inflammatory patterns² across the spectrum of pathologic descriptions. Because the cases we report here had relatively recent onset, none demonstrated usual interstitial pneumonia as reported by Morell et al⁶ in a group of patients with chronic HP misdiagnosed as idiopathic pulmonary fibrosis. Koschel et al⁹ reported 13 cases of HP caused by recent exposure to GDD duvets, pillows, or

Table 5
Pulmonary Function

Patient No.	Before avoidance			2 Months after avoidance			Current		
	FVC, %	FEV ₁ /FVC, %	Dlco, %	FVC, %	FEV ₁ /FVC, %	Dlco, %	FVC, %	FEV ₁ /FVC, %	Dlco, %
1	70	99	53	97	93	82	96	98	73
2	50	80	ND	100	100	ND	ND	ND	ND
3	61	112	40	63	109	ND	73	106	63
4	96	106	63	106	114	ND	112	105	67
5	84	81	ND	116	89	ND	117	96	96
6	93	100	86	102	102	ND	105	98	107
7	84	85	60	86	99	ND	90	101	ND
8	49	100	25	56	98	39	ND	ND	ND
9	58	107	60	63	113	ND	ND	ND	ND
10	85	76	47	LFU	LFU	LFU	LFU	LFU	LFU
11	66	110	44	ND	ND	ND	ND	ND	ND
12	78	110	55	81	110	ND	ND	ND	ND

Abbreviations: Dlco, carbon monoxide diffusing capacity of the lung; FEV₁, forced expiratory volume in 1 second; FVC, forced vital capacity; LFU, lost to follow-up; ND, not done.

Table 6
List of Other Causes of HP

Other cause	No. of patients		
	Total	Female	Male
Microbial contamination of home	26	20	6
Birds in the home	11	7	4
Contaminated A/C system	8	5	3
Microbial contamination of workplace	7	5	2
Possible GDD	4	1	3
Unknown	9	5	4
Miscellaneous	3	1	2

Abbreviations: A/C, air conditioning; GDD, goose and duck down.

both, in which the biopsy patterns in 9 patients revealed a lymphocytic alveolitis ($n = 8$), granulomas ($n = 3$), BOOP ($n = 2$), and usual interstitial pneumonia ($n = 1$). Ohtani et al¹⁰ described 26 patients with chronic bird fancier's lung in which the biopsy specimens were reanalyzed to meet the criteria as presented in the 2002 American Thoracic Society/European Respiratory Society consensus classification of the idiopathic interstitial pneumonias.²⁵ These patients were considered to have a usual interstitial pneumonia pattern ($n = 11$), fibrotic NSIP ($n = 8$), cNSIP ($n = 5$), and BOOP ($n = 2$), demonstrating a variety of patterns in chronic HP.

None of our patients elected to undergo a direct natural challenge by reusing the GDD bedding that had originally caused their disease. One of the exacerbations of our featured case was an indirect exposure, within her second home, in which stuffed furniture and decorative pillows were causative. Other reports have noted similar indirect exacerbations. Harada et al¹⁴ reported a case of HP caused by sleeping with a feather duvet. Avoidance led to remission. An exacerbation occurred a year later caused by a feather duvet of a housemate's separate bed within the same room. Kondo et al¹⁵ reported a case of HP caused by feather duvet with an exacerbation occurring when the patient was visiting in a hospital in which feather pillows were used.

Avoidance challenge procedures may be more difficult to interpret in chronic vs acute or subacute HP presentations because in the chronic advanced stage of disease inflammatory markers may not be elevated. Because of the frequency with which feather bedding has been implicated as causative in chronic as well as acute and subacute HP, a logical approach is to avoid this potential antigen in all cases of unexplained interstitial lung disease.

In the remaining 64 cases of HP, seen during this 8-year period, a number of causes were discovered. In some instances, the specific inciting agent could not be discerned, as was the case in 25% of 85 cases reported by Hanak et al.⁵ Jacobs et al²⁶ reported a case of home-induced HP demonstrating the similarities between avoidance challenge techniques and specific antigen challenges. This similarity provoked the conclusion that an environmental challenge is safer and more effective in both identifying the causative environment and determining whether remediation efforts had been effective.²⁷ In a recently reported case,²⁸ a causative environment was identified without a confirmed antigen. Simply moving to a different residence and removal of GDD was a successful intervention. After the home investigations and modest remediation, in which no identifiable causative factors were discovered, the patient was returned to the house, again without GDD exposure. Exacerbation of symptoms and inflammatory markers after 27 days of exposure confirmed the home as the causative environment and also ruled out a role of GDD. This prompted additional more in-depth investigation, leading to effective remediation of a wall contamination not previously identified. This case, as well as one reported previously,²⁷ highlights the observation that patients during a natural challenge may not respond for days to weeks after reentering a causative environment. In contrast to HP caused by an

unidentified antigen in a home, a case²⁹ reported during this period had a more classic presentation caused by a large spore of *Fusarium vasinfectum*. Positive serum precipitins and cultures from a cluttered, dank home were the primary factors in identifying a causative antigen.

In summary, the home is the most common causative environment of HP worldwide, and female patients have become dominantly affected. The most common causative antigens include avian, from live birds or GDD, and mold in home structure or A/C systems. GDD is becoming an increasingly popular material for stuffing pillows, duvets, comforters, furniture, and clothing. In our population, GDD was the causative antigen of HP in 15% of all HP cases and in 37.5% of patients sleeping with GDD. Lung biopsy results in this study, and in others, vary across the spectrum of pathologic findings described for interstitial lung disease. In patients with data suggestive of a diagnosis of HP, the environmental history is key to determining if GDD is present in home furnishings. In patients with an acute or subacute onset of symptoms, immediate removal of down-containing materials from the environment may confirm the diagnosis and identify the causative antigen, obviating a need for additional testing, invasive procedures, and environmental inspections for potentially costly remediation. These data demonstrate the need in all cases of interstitial lung disease of unknown cause to strongly consider HP and obtain a thorough history of the patient's environment. A logical first approach with all forms of interstitial lung disease of unknown cause is avoidance of GDD.

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