

Original Article

Impact of the Asthma Quality Assessment Program on Burden of Asthma

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What is already known about this topic? The Korean Health Insurance Review and Assessment Service launched the National Asthma Quality Assessment Program from 2013 to assess whether patients with asthma in Korea were well managed.

What does this article add to our knowledge? The Asthma Quality Assessment Program conducted by the Korean government led to improvements in both the asthma management protocol and prognosis in Korea; however, the effect was restricted to the assessment term.

How does this study impact current management guidelines? Steady application of national management programs, such as Asthma Quality Assessment Program, will encourage patients and clinicians to follow recommended guidelines. Improved compliance of asthma management will be helpful to steadily reduce the social and economic burden of asthma.

BACKGROUND: In 2013, the Korean Health Insurance Review and Assessment Service launched the Asthma Quality Assessment Program (AQAP) to assess whether patients with asthma were well managed.

OBJECTIVE: To show the impact of the AQAP on the medical utilization behavior for asthma.

METHODS: We used claims data linked with the results of the AQAP performed between July 2013 and June 2017. Asthma was determined when subjects visited hospital for asthma. Subjects who used asthma medications on at least 2 different occasions were assessed by the AQAP (assessed subjects [Ass]; not-assessed subjects [NASs]). The AQAP evaluated conduction rate of the pulmonary function test, routine visit rate, and prescription rate

of asthma medications. Primary clinics were classified as “good” and “not-good” clinics according to the results of the AQAP.

RESULTS: Of the 4.3 million subjects with asthma screened, about 0.8 million were assessed by the AQAP annually. Both the conduction rate of pulmonary function test and the prescription rate of inhaled corticosteroids in the ASs and NASs were improved. In addition, the risk of admission and yearly all-cause mortality were significantly reduced (risk reduction rate, 17.1 and 24.4%, respectively, both $P < .001$) in the AS group compared with the NAS group. However, effects of the AQAP varied according to the subgroup, and they were restricted to the assessment term. In addition, the admission rate and all-cause mortality were decreased by 94.7% and 45.3%, respectively, in “good” clinics as opposed to the “not-good” clinics.

CONCLUSIONS: Performing the AQAP improved both the management protocol and prognosis of asthma in Korea. © 2020 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2020;■:■-■)

Key words: Asthma; Quality assessment; Prognosis; Mortality; Clinical outcomes

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INTRODUCTION

Asthma is a chronic airway disease requiring steady monitoring, appropriate medication, and continuous management.¹ The pulmonary function test (PFT) is regularly performed to estimate the progress of lung function decline and predict the prognosis of asthma.² Inhaled corticosteroids (ICSs) are a fundamental therapeutic option proven to lower both mortality and admission rates.³ Although the inhaled short-acting β_2 -agonist (SABA) is another option for asthma management as a quick reliever for acute symptoms, it should always be prescribed combined with ICSs as recommended in the Global Initiative

Abbreviations used

AS- assessed subject
 AQAP- Asthma Quality Assessment Program
 HIRA- Health Insurance Review and Assessment Service
 ICS- inhaled corticosteroid
 NAS- not-assessed subject
 PFT- pulmonary function test
 SABA- short-acting β_2 -agonist

for Asthma guidelines.⁴ The Global INitiative for Asthma guidelines also recommend regular monitoring and the prescription of ICS-containing medication for all patients with asthma.^{5,6} In addition, leukotriene receptor antagonist can be another choice to control asthma.⁷ However, the real-life clinical situation differs from the theory. Several patients experiencing asymptomatic prolonged asthma may be reluctant to regularly visit hospital and continuously use medication.⁸ The prescription rate of ICSs is still low, whereas SABA monotherapy is predominantly prescribed in clinics worldwide.^{8,9}

All hospitals in South Korea claim medical expenses through the Korean Health Insurance Review and Assessment Service (HIRA), and this committee approves insurance reimbursement from National Health Insurance Service, which supports almost the entire national population. HIRA collects all information relative to diagnostic codes and prescription reported by physicians for insurance claims. In 2013, HIRA launched the National Asthma Quality Assessment Program (AQAP) to improve patient management protocols and the clinical outcomes of patients with asthma.¹⁰ The AQAP assessed whether medical institutions in Korea correctly managed patients with asthma according to the following criteria: (a) regular PFT assessment, (b) regular follow-up visits and routine patient monitoring, and (c) rate of ICS prescription. The AQAP scored the results of the assessment and released the results to the public through its website.¹¹ Centers with similar goals can be found worldwide; however, there have been no national health insurance agencies investigating the general management of asthma specifically.¹²⁻¹⁴

Therefore, we aimed to show the impact of the AQAP conducted by HIRA on management protocols and clinical outcomes of asthma in Korea.

METHODS**The National Asthma Quality Assessment Program**

The AQAP was conceived by the Korean government in 2013 and is conducted yearly (a) to evaluate how patients with asthma are managed across all Korean medical institutions; (b) to improve the quality of the asthma management protocols in clinics; and (c) to improve the prognosis of patients with asthma. Briefly, the AQAP evaluated the following items: (1) conduction of the PFT at least once during the 1-year assessment term; (2) whether subjects with asthma visited medical clinics for regular follow-up (ie, at least 3 times during the assessment term); and (3) prescription rate of asthma medications. Specifically, prescription rates of ICSs and leukotriene receptor antagonists (defined as “good medication protocol”) were evaluated, as well as practices defined as “bad medication protocol”: long-acting β_2 -agonist without ICS, SABA without ICS, and oral steroids without ICS.

In addition, HIRA classified all the national primary clinics, after excluding clinics with fewer than 10 patients with asthma, into

“good” and “not-good,” as indicated by the AQAP results. “Good” clinics represented facilities that were awarded an above-average rating in all the above-mentioned items. Specifically, conduction rate of PFT greater than or equal to 20%, regular follow-up visit rate greater than or equal to 70%, ICS prescription rate greater than or equal to 20%, and ICS or leukotriene receptor antagonist prescription rate greater than or equal to 50% in all patients with asthma attending clinics. “Not-good” clinics represented facilities that received either a below-average rating in at least 1 of the above-mentioned items or were in the bottom 10% in at least 1 of the above-mentioned items.

Data generation from claims data linked with the AQAP

Korea has a national health insurance system that uniquely covers all Korean citizens. Therefore, information relative to all medical visits and medical records is included in the claims data. We analyzed the results of the AQAP and AQAP-linked claims data generated from July 1, 2013, to June 30, 2017.

Definition of subjects with asthma from the HIRA database

Subjects with asthma were defined as patients who visited the hospital (including outpatient and inpatient visits) at least once because of asthma during the assessment term. Only those subjects who met the following criteria during the assessment term were assessed by this program (assessed subjects [ASs]): (1) age 15 years or more; (2) *International Classification of Diseases, Tenth Revision* codes for asthma (J45 and J46) as primary diagnosis or first subdiagnosis; and (3) prescription of asthma medications on at least 2 occasions during outpatient visits¹⁵ or prescription of asthma medication following an outpatient visit and admission with systemic corticosteroids during the assessment term. In 2013, this definition of AS (for asthma) was established by the HIRA committee according to the authoritative opinions of respiratory and allergy experts in Korea. Since then, this definition has been commonly used by many clinical researchers, medical statisticians, and even the HIRA committee in Korea.^{2,10,16} All other subjects with asthma were not assessed by the AQAP (not-assessed subjects [NASs]).

Clinical outcomes

We defined the clinical outcomes as follows: (a) frequency of admission to the medical clinics due to asthma symptoms (with the *International Classification of Diseases, Tenth Revision* code of asthma [J45 and J46]); and (b) the yearly all-cause mortality (as the cause of death could not be assessed).

Study designs

Figure E1, A, in this article's Online Repository at www.jaci-inpractice.org shows the study design and patient inclusion in the study. First, we selected the ASs: (a) July 1, 2013, to June 30, 2014 (AS-2013); (b) July 1, 2014, to June 30, 2015 (AS-2014); (c) July 1, 2015, to June 30, 2016 (AS-2015); and (d) July 1, 2016, to June 30, 2017 (AS-2016). Next, the NAS group was defined (ie, NAS-2013, NAS-2014, NAS-2015, and NAS-2016). The outcomes of the 8 groups were evaluated at each assessment term. Subsequently, we calculated the risk reduction rate over a 4-year period in the AS group compared with the NAS group using the following equation: $1 - (\text{relative increase in risk in the AS group over 4 years} / \text{relative increase in risk in the NAS group over 4 years})$, where a high positive value suggested positive risk reduction effects of the AQAP in the AS group compared with that in the NAS group. Second, we selected a

subgroup including subjects with asthma assessed by the AQAP for 4 consecutive years, and the serial outcomes were evaluated. Third, we designed a matching analysis to compare the serial changes in outcomes within the same subjects and minimized the confounding factors. Specifically, age, sex, and type of medical institutions (ie, tertiary hospital, secondary hospital, hospital, nursing hospital, and others) attended were matched. Last, we compared outcomes according to the type of medical clinic attended (“good” or “not-good” clinics) in the AS-2016 group and the NAS-2016 group, respectively. Subjects who did not visit any clinic or subjects who visit both “good” and “not-good” clinics were excluded from this study.

Ethics requirements

This study was approved by the Institutional Review Board of Severance Hospital (number 4-2018-0956). The informed consent requirement was waived because of the minimal risk to patients and the retrospective nature of this study.

Statistical analyses

We compared clinical characteristics, management practice, and prognosis between groups using the χ^2 test (categorized variables), independent sample *t* test, and ANOVA test (continuous variables). A generalized linear model was used to estimate and compare the risk reduction rate over 4 years between AS and NAS groups. Propensity score matching was used to reduce the imbalance of age, sex, and types of institutions. Data were analyzed using SAS Enterprise version 6.1 (SAS Institute Inc, Cary, NC). A *P* value of less than .05 was considered to indicate statistical significance.

RESULTS

Clinical characteristics, management practice, and prognosis of total asthma subjects

Data from a total of 4,386,402, 4,386,764, 4,362,844, and 4,329,248 subjects with asthma were reviewed. The mean age was about 49.2 to 51.7 years, and the population was mostly female (about 60%). Interestingly, the ICS prescription rates and PFT conduction rates steadily increased with the number of AQAP years, whereas the prescription rates for SABA steadily decreased for subjects with asthma overall (all *P* values for trend < .001). The mean medical institute admission frequency due to asthma was about 0.018 to 0.020/y, whereas the medical costs resulting from asthma were about \$764.20 to 1157.10/y. Finally, the all-cause mortality was about 0.8% to 1.1% per year (see Table E1 in this article's Online Repository at www.jaci-inpractice.org).

Study population

Figure E1, B, illustrates the study population. Of the 4.3 million patients with asthma, about 0.8 million (18.6%) were annually assessed by the AQAP. In contrast, 46% of the total population was evaluated by the AQAP at least once over a period of 4 years, whereas only 3% of patients were assessed for 4 consecutive years.

Clinical characteristics, management practice, and prognosis of ASs and NASs

In the AS groups, the PFT conduction rate improved from 23.9% (2013) to 31.3% (2016), while the ICS prescription rate increased from 27.9% (2013) to 36.7% (2016) (both *P* values for trend < .001) (Table I). In the NAS groups, the PFT conduction rate was lower than that in the AS groups; however, it steadily increased from 2013 (6.3%) to 2016 (8.0%) (*P* values

for trend < .001). Similarly, the ICS prescription rate was also lower than that in the AS groups, although it improved from 2013 (3.5%) to 2016 (4.6%) (*P* values for trend < .001) (Table II).

Comparison of the changes in variables and risk reduction rate over 4 years between ASs and NASs

Both the PFT conduction and the ICS prescription rates increased over 4 years for both groups. Significant changes in the prescription pattern for most asthma medications were observed in both the AS and the NAS groups. Furthermore, although the admission frequency to medical clinics because of asthma slightly decreased in the AS group over the 4 years (−5.4%), it increased in the NAS group (+14.8%) (risk reduction rate, 17.1%; *P* < .001). Finally, the all-cause mortality greatly increased in the NAS group over 4 years (27.3%), whereas it decreased in the AS group (−3.8%) (risk reduction rate, 24.4%; *P* < .001) (Table III; see Figure E2 in this article's Online Repository at www.jaci-inpractice.org).

Serial changes in management practice and prognosis in subjects assessed by the AQAP for 4 consecutive years

All the above-mentioned variables were high at baseline and remained constant over the assessment period in subjects evaluated by the AQAP over 4 consecutive years. However, SABA prescription rate decreased, and admission frequency was also significantly decreased (Table IV; see Figure E3 in this article's Online Repository at www.jaci-inpractice.org).

Matching analyses

Matching analyses were conducted in the NAS-2016 and AS-2016 groups (see Table E2 in this article's Online Repository at www.jaci-inpractice.org). Although both the PFT conduction rate and the ICS prescription rate in the matched AS-2016 group peaked in 2016, these sharply decreased in 2017. Similarly, the admission frequency in the matched AS-2016 group increased in 2016 and then decreased in 2017. In contrast, the above values were not greatly influenced by the assessment term in the matched NAS-2016 group (see Tables E3 and E4 and Figure E4, A-C, in this article's Online Repository at www.jaci-inpractice.org). Similar results were observed in the matched data for 2014 (see Tables E5-E7 in this article's Online Repository at www.jaci-inpractice.org and Figure E4, D-F).

Comparison of the management practice and prognosis of subjects with asthma according to the type of clinics attended

In the AS-2016 group, subjects with asthma who visited the “good” clinics reported a higher ICS prescription rate (63.8%) and a lower oral steroid prescription rate (46.1%) than those who attended the “not-good” institutions (32.7% and 65.6%, respectively). Furthermore, the mean admission frequency because of asthma was higher in subjects who visited the “not-good” clinics (0.057/y) than that in subjects who attended the “good” clinics (0.003/y; *P* < .001). Similarly, the all-cause mortality was higher in the former (1.59%/y) than in the latter (0.87%/y) (*P* < .001) (Table V). Similar results were observed in the NAS-2016 group (see Table E8 in this article's Online Repository at www.jaci-inpractice.org).

TABLE I. Clinical characteristics, management practice, and prognosis of ASs

Variables	AS-2013 (n = 831,613)	AS-2014 (n = 818,771)	AS-2015 (n = 776,882)	AS-2016 (n = 759,132)
Clinical characteristics				
Age (y), mean $\pm$ SD	55.1 $\pm$ 17.7	55.8 $\pm$ 17.8	55.8 $\pm$ 17.9	56.1 $\pm$ 18.0
Sex: female, n (%)	501,865 (60.3)	497,224 (60.7)	465,880 (60.0)	449,159 (59.2)
Management practice, n (%)				
PFT conduction	198,512 (23.9)	207,427 (25.3)	222,872 (28.7)	237,818 (31.3)
ICS prescription	231,826 (27.9)	244,387 (29.9)	260,409 (33.5)	278,500 (36.7)
Oral steroid prescription	551,198 (66.3)	543,628 (66.4)	512,916 (66.0)	509,164 (67.1)
LTRA prescription	463,071 (55.7)	471,398 (57.6)	460,571 (59.3)	421,069 (55.5)
SABA prescription	113,169 (13.6)	107,753 (13.2)	108,284 (13.9)	112,060 (14.8)
Prognosis				
Frequency of admission for asthma per year, mean $\pm$ SD	0.059 $\pm$ 0.406	0.062 $\pm$ 0.414	0.056 $\pm$ 0.382	0.056 $\pm$ 0.382
All-cause mortality in the next year, n (%)	13,147 (1.58)	12,262 (1.50)	11,481 (1.48)	11,541 (1.52)

LTRA, Leukotriene receptor antagonist.

TABLE II. Clinical characteristics, management practice, and prognosis of NASs

Variables	NAS-2013 (n = 3,554,789)	NAS-2014 (n = 3,567,993)	NAS-2015 (n = 3,585,962)	NAS-2016 (n = 3,570,116)
Clinical characteristics				
Age (y), mean $\pm$ SD	47.8 $\pm$ 18.7	48.8 $\pm$ 18.7	49.9 $\pm$ 18.6	50.8 $\pm$ 18.5
Sex: female, n (%)	2,129,932 (59.9)	2,137,053 (59.9)	2,158,493 (60.2)	2,159,858 (60.5)
Management practice, n (%)				
PFT conduction	224,568 (6.3)	249,092 (7.0)	274,914 (7.7)	285,640 (8.0)
ICS prescription	123,234 (3.5)	143,950 (4.0)	154,139 (4.3)	164,192 (4.6)
Oral steroid prescription	1,646,339 (46.3)	1,678,626 (47.1)	1,687,928 (47.1)	1,702,507 (47.7)
LTRA prescription	673,139 (18.9)	746,966 (20.9)	770,740 (21.5)	634,714 (17.8)
SABA prescription	72,096 (2.0)	76,491 (2.1)	77,859 (2.2)	79,838 (2.2)
Prognosis				
Frequency of admission for asthma per year, mean $\pm$ SD	0.008 $\pm$ 0.156	0.010 $\pm$ 0.183	0.009 $\pm$ 0.1812	0.009 $\pm$ 0.197
All-cause mortality in the next year, n (%)	27,493 (0.8)	22,524 (0.6)	29,805 (0.8)	35,136 (1.0)

LTRA, Leukotriene receptor antagonist.

DISCUSSION

The AQAP is a unique national program conducted by HIRA in Korea. The aim of the AQAP is to assess the level of treatment protocols achieved for patients with asthma targeting all national medical institutions in Korea. The results of the AQAP are publicly accessible, and both patients with asthma and health care providers are informed regarding whether the quality of the medical institutions is “good” or “not-good” in terms of asthma management. This study, for the first time, confirmed that the Korean AQAP positively influenced the quality of medical service. Following its launch in 2013, both the PFT conduction rate and the prescription rate of ICSs indeed increased. In addition, the improvement in the management protocol was superior in the AS group compared with the NAS group. This study suggested that the AQAP and the relative feedback of the results of AQAP in public encouraged health care providers to properly manage patients with asthma.

The AQAP also influenced asthma treatment and prognosis; however, its effects were different for the AS and NAS groups. The coverage of medical insurance has expanded in Korea (supported by the Korean government), and national income has increased. We speculated that it leads patients to visit hospitals more easily and frequently. Consequently, admission frequency

for asthma exacerbation was increased in the NAS group. Nonetheless, asthma-related admission frequency decreased in the AS group. Similarly, although the mortality rate increased in the NAS group, the opposite was seen in the AS group. These results suggest that the AQAP positively affected the prognosis of asthma, especially in the AS group. To benefit additional patients with asthma, the Korean government should ensure that all patients with asthma are enrolled in the AQAP. In addition, we should also consider broadening the range of ASs to maximize its beneficial effects.

Some health care centers have attempted to improve management protocols conducted at their individual centers; however, the target disease is an acute life-threatening disease including acute coronary syndrome, stroke, and pneumonia.^{14,17} In 1988, a World Health Organization meeting was held to overcome chronic airway disease, and the “Global Strategy for Asthma Management and Prevention” was developed, as the first global asthma program. Following its launch, asthma-related mortality was reduced worldwide, including Korea (48%) and Japan (69%).¹⁸ Some studies also confirmed that small-scale programs with regular onsite personalized supervision and coaching influenced the improvement of medical services.¹⁹

TABLE III. Comparison of the changes in variables and risk reduction rate over 4 y between ASs and NASs

Variables	ASs	NASs	Risk reduction rate over 4 y in ASs compared with NASs	P value for comparison between ASs and NASs
Management practice				
PFT conduction rate	+31.0%	+27.0%	−3.6%	<.001
ICS prescription rate	+31.5%	+32.6%	+0.8%	<.001
Oral steroid prescription rate	+1.2%	+3.0%	+1.7%	<.001
LTRA prescription rate	−3.8%	−6.1%	−6.1%	<.001
SABA prescription rate	+8.4%	+10.3%	1.6%	<.001
Prognosis				
Frequency of admission for asthma	−5.4%	+14.8%	+17.1%	<.001
All-cause mortality in the next year	−3.8%	+27.3%	+24.4%	<.001

LTRA, Leukotriene receptor antagonist.

TABLE IV. Serial changes in management practice and prognosis of subjects assessed by the AQAP for 4 consecutive years

Variables	2013 (n = 133,178)	2014 (n = 133,178)	2015 (n = 133,178)	2016 (n = 133,178)	Changes, %
Management practice, n (%)					
PFT conduction	50,983 (38.3)	50,635 (38.0)	53,500 (40.2)	55,520 (41.7)	+8.9%
ICS prescription	88,549 (66.5)	87,104 (65.4)	85,188 (64.0)	85,009 (63.8)	+7.5%
Oral steroid prescription	80,202 (60.2)	83,745 (62.9)	85,389 (64.1)	86,178 (64.7)	−4.1%
LTRA prescription	84,314 (63.3)	85,955 (64.5)	86,137 (64.7)	82,937 (62.3)	−1.6%
SABA prescription	25,565 (19.2)	23,544 (17.7)	21,216 (15.9)	18,871 (14.2)	−26.0%
Prognosis					
Frequency of admission for asthma per year, mean ± SD	0.115 ± 0.545	0.117 ± 0.573	0.104 ± 0.541	0.110 ± 0.590	−4.3%

LTRA, Leukotriene receptor antagonist.

The positive effects of AQAP varied in subjects with asthma. Weak effects were observed in the patient subgroup assessed by the AQAP for 4 consecutive years. This subgroup reported higher PFT conduction rates and increased prescription rates of all asthma medications at baseline (except for oral steroids). A higher admission risk and medical costs for asthma were also found. This subgroup required multiple asthma medications and was highly dependent on the availability of high-quality medical services, which may imply that this subgroup of subjects had more severe asthma. Unfortunately, this group did not show a sufficient improvement. Therefore, we suggest that the AQAP might have varying effects on different subgroups.

Furthermore, we found that the positive effects of the AQAP were restricted to the assessment period. Although asthma is a chronic airway disease associated with frequent asthma attacks, some patients with mild symptoms are reluctant to conduct prolonged monitoring and follow-up visits. Indeed, several studies have previously reported that more than half the patients with asthma did not attend their follow-up visits.^{8,20} Therefore, the sharp decrease in the above values may also suggest the discontinuation of visits to the hospital. Furthermore, although the decrease in the ICS prescription rate is steep, the effect on admission rates is relatively gradual, meaning that some subjects without PFT assessment results or who were not receiving ICS treatment were also admitted to the hospital because of an asthma attack. Consequently, sustained long-term application of the AQAP should be considered to maintain its beneficial effects.

The AQAP is able to discriminate between “good” and “not-good” clinics. Specifically, “good” clinics showed better

management practice than the “not-good” clinics. In addition, subjects with asthma attending “good” clinics had a better prognosis than those visiting the “not-good” clinics. Specifically, subjects attending the “good” clinics showed lower admission risk (94.7% reduction) and lower mortality rates (45.3% reduction) than those attending the “not-good” clinics. This suggested that the type of clinic visited by subjects has a decisive role in their asthma prognosis. These considerable effects are even comparable to those of corticosteroids or recently developed biologics.^{21–23} The government needs to educate and encourage clinics to obtain good results from AQAP.

However, the overall difference in asthma prognosis between “good” and “not-good” clinics should be carefully interpreted. This dramatic difference can be attributed to the following reasons. First, some clinics include subjects with severe asthma presenting chronic respiratory failure and requiring home oxygen or ventilator support, and are not able to undergo PFT assessment, rendering these clinics as “not-good” (because of a lack of PFT conduction), which in turn defines a clinic with poor asthma prognosis. Second, relatively large-scale clinics possessing inpatient rooms may easily be classified as “not-good.” Subjects with well-controlled asthma who frequently visit small-scale clinics with no inpatient rooms can be referred to large-scale clinics when their asthma exacerbation occurred. Unscheduled visits and admissions can classify such clinics as “not-good” (because of a lack of continued follow-up visits and PFT conduction), which additionally results in poor prognosis. For the above reasons, we should not only carefully accept this result but also cautiously apply it to the clinical fields.

TABLE V. Comparison of the management practice and prognosis in subjects with asthma according to the type of clinics attended in AS-2016

Variables	Subjects who always visit the "good" clinics (n = 7,740)	Subjects who always visit the "not-good" clinics (n = 528,244)	P value
Clinical characteristics			
Age (y), mean $\pm$ SD	52.3 $\pm$ 17.8	55.7 $\pm$ 18.2	<.001
Sex: female, n (%)	3,707 (47.9)	307,160 (58.2)	<.001
Management practice, n (%)			
PFT conduction	2,821 (36.5)	145,349 (27.5)	<.001
ICS prescription	4,938 (63.8)	172,738 (32.7)	<.001
Oral steroid prescription	3,570 (46.1)	346,359 (65.6)	<.001
LTRA prescription	4,473 (57.8)	280,851 (53.2)	<.001
SABA prescription	1,605 (20.7)	74,983 (14.2)	<.001
Prognosis			
Frequency of admission for asthma per year, mean $\pm$ SD	0.003 $\pm$ 0.152	0.057 $\pm$ 0.398	<.001
All-cause mortality in the next year, n (%)	67 (0.87)	8,415 (1.59)	<.001

LTRA, Leukotriene receptor antagonist.

Given that 4.3 million subjects with asthma were reported in this study and that 51.8 million people live in South Korea, the prevalence of asthma was calculated to be around 8.3%. Of all the subjects with asthma, 18% to 19% were evaluated by the AQAP during the assessment term (for 1 year). Only 3% of the subjects with asthma continuously visited the hospital for 4 consecutive years. This implies that most patients with asthma do not visit hospital regularly, and they visit hospital whenever they feel ill. Furthermore, many subjects (54%) have never been subjected to the AQAP. We recommend that additional subjects with asthma should be assessed by the AQAP and controlled by the health care system to receive high-quality medical services and achieve improved asthma prognosis.

This study has some strengths. First, this is the first study to reveal positive impact from the application of the national health insurance program, the AQAP, and the general prognosis of asthma using different study designs. Second, the complete national cohort database of Korea was assessed in this study, resulting in a reduction in selection bias. Finally, 4 different study designs (comparison between ASs and NASs; subgroup analysis in subjects assessed over consecutive years, matching analysis, and comparison according to the type of medical clinic) were used to reveal the impact of the AQAP, and considering that the outcomes from each design resulted in similar findings, our conclusions are well supported.

Limitations to the study should also be considered. First, we only used diagnostic codes to define subjects with asthma (ASs and NASs); thus, the following confounding cases might have been included in the study: (a) unconfirmed suspicion of asthma, (b) diagnosis code because of the coverage of the national insurance, and (c) forgot to delete diagnostic code after test. In addition, the prescription rate of asthma medication in the AS group may be overestimated in this setting. Moreover, patients with mild asthma with intermittent symptoms might be classified as NASs. Certainly, these definitions have some limitations; however, we feel that these definitions represent an acceptable approach to define patients with asthma in this situation in which HIRA data include only diagnostic codes and medication use, as used in previous studies.^{10,16} Second, other parameters (ie, admission for asthma, medical cost for asthma, classification of institutes [good or not-good]) were also derived by operational

definitions. Third, this is not a randomized controlled trial; therefore, we could not show the direct effects of the AQAP. Fourth, assessed variables, including the prescription rate of ICSs, do not represent the "appropriateness" of asthma medication as suggested by Global INitiative for Asthma guidelines, directly.²⁴ Fifth, there are some limitations that do not allow generalization of this study to nations without national health care systems. Sixth, we should carefully interpret the results in this study by considering clinical significance, because studies involving big data such as ours may lead extremely small differences to be statistically significant, which may not be clinically significant. Last, there might have been unintended negative effects of the AQAP, for example, intentional removal of diagnostic codes by doctors, overuse of asthma medications, and avoidance of noncompliant patients.

CONCLUSIONS

The AQAP, conceived by the health insurance bureau, improved both the management protocol and the prognosis of asthma (especially in the AS group) in Korea. In addition, the effects of the AQAP are good but are restricted to the assessment term. Finally, the management protocol and prognosis were strongly affected by the type of clinic visited by the patients. Therefore, we suggest that the continued application of this program will be helpful to improve clinical outcomes in patients with asthma.

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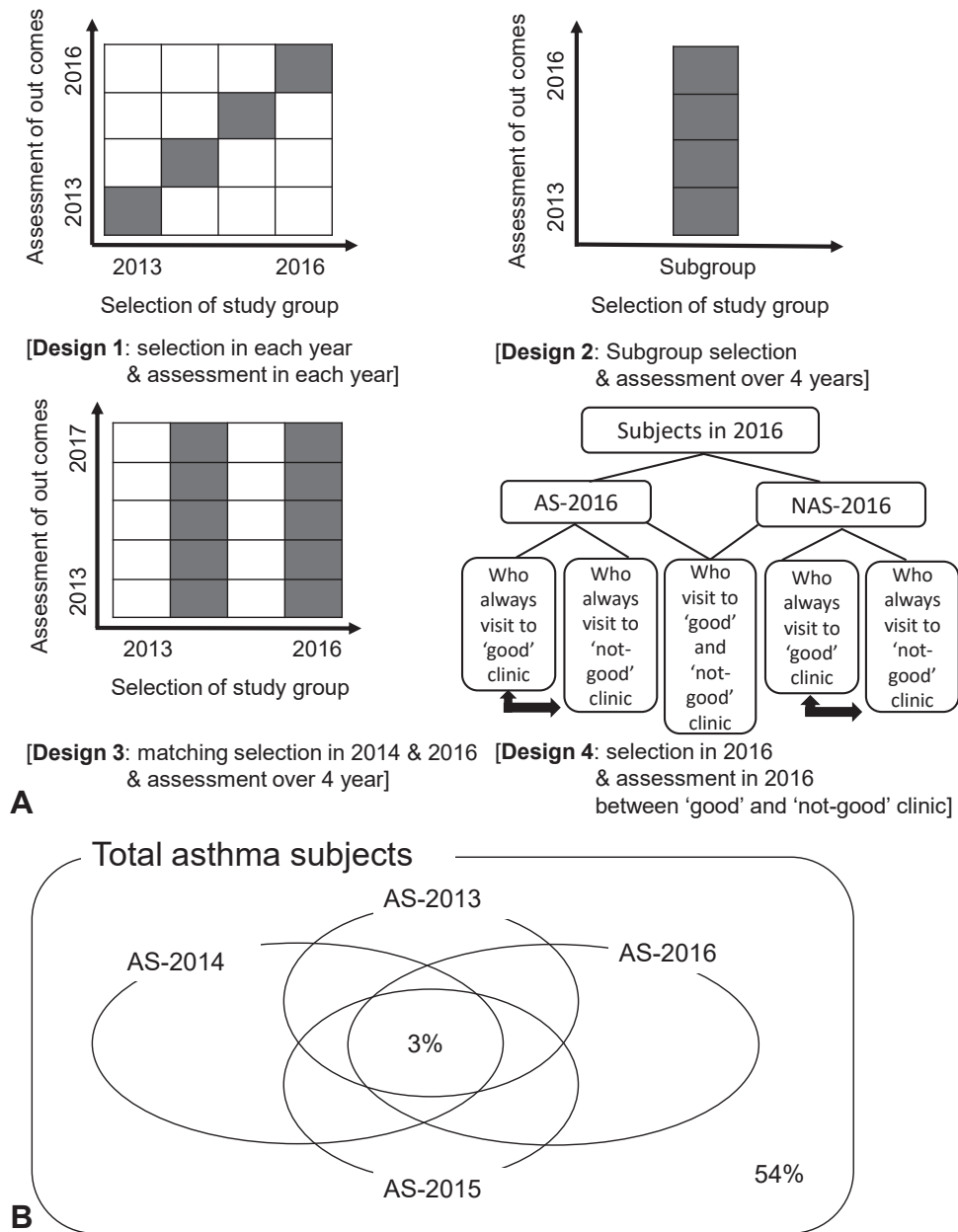


FIGURE E1. (A) Study designs and (B) study population.

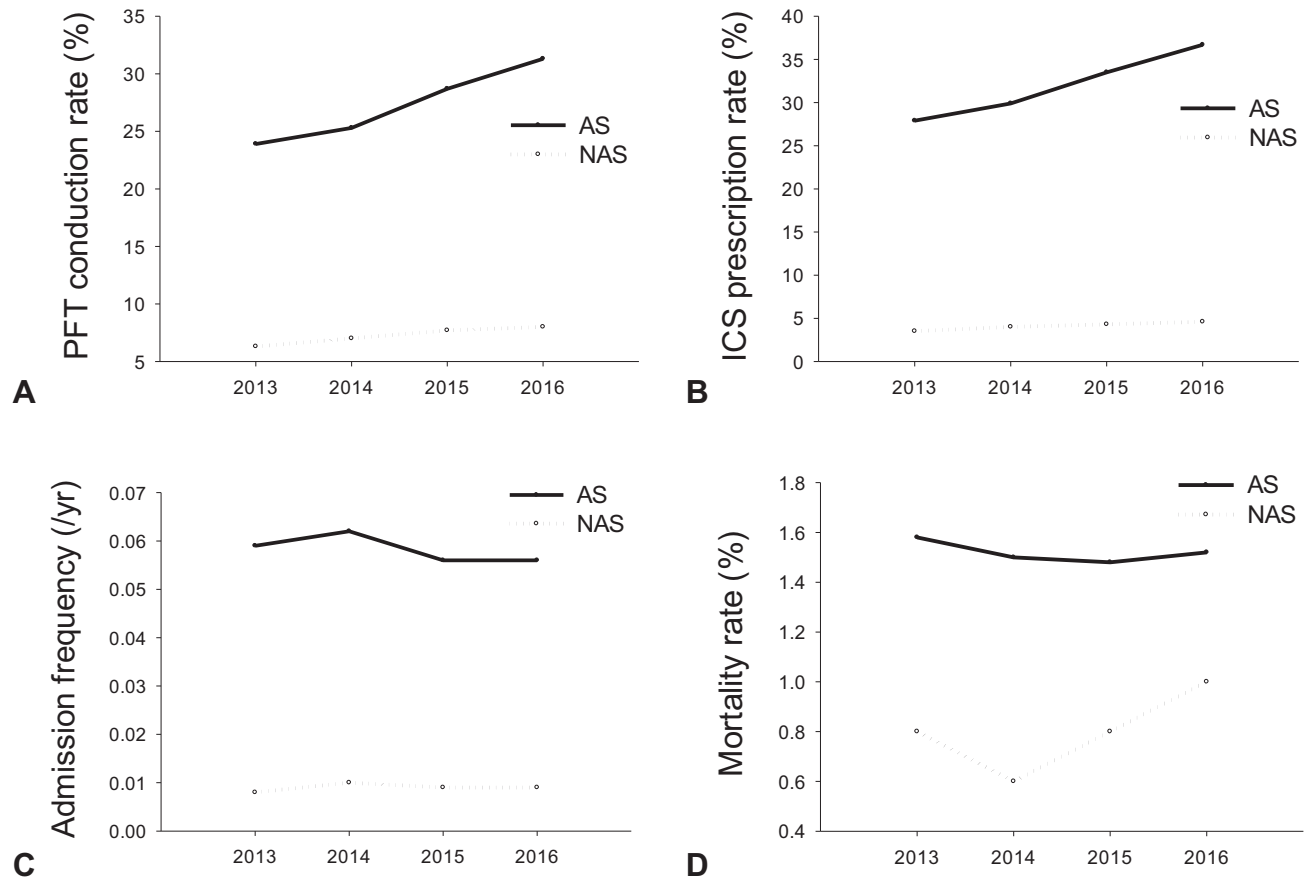


FIGURE E2. Changes in (A) PFT conduction rate, (B) ICS prescription rate, (C) admission frequency, and (D) mortality rate in AS and NAS groups.

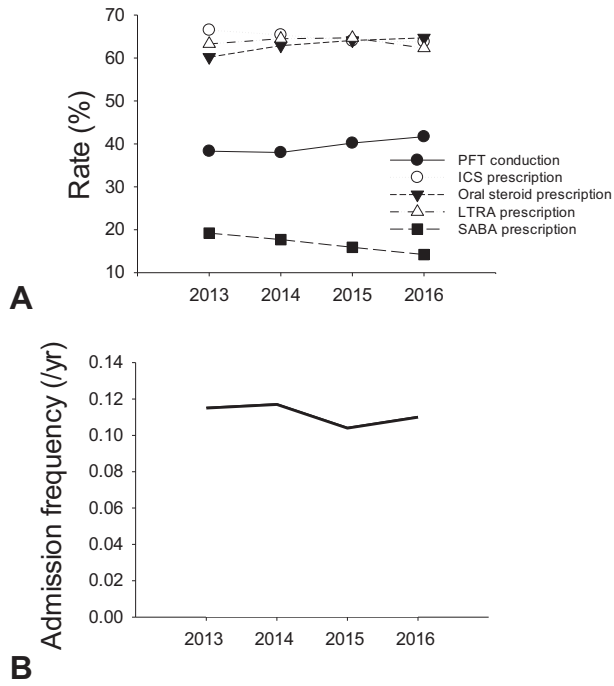


FIGURE E3. Changes in **(A)** management practice and **(B)** prognosis of subjects assessed by the AQAP for 4 consecutive years. *LTRA*, Leukotriene receptor antagonist.

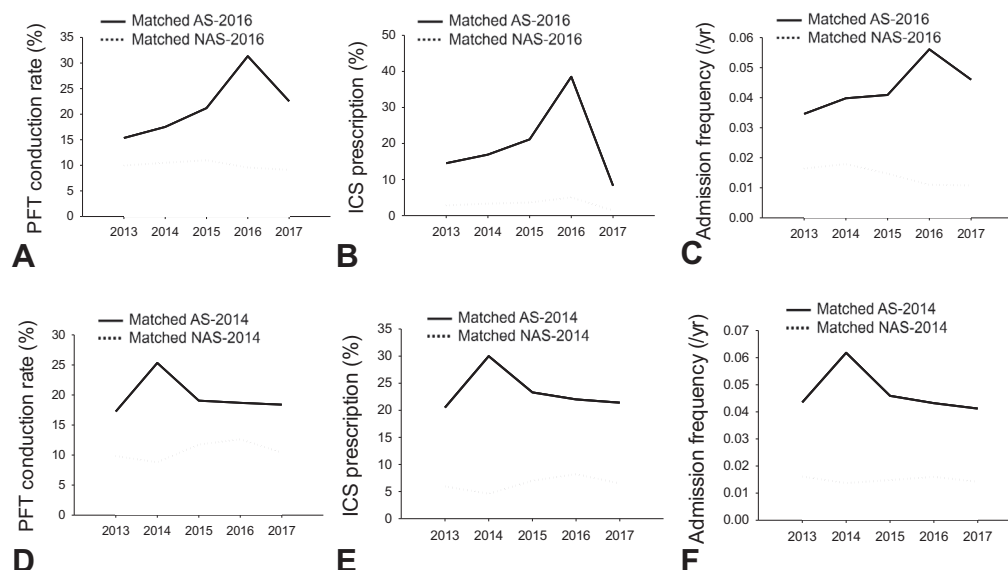


FIGURE E4. Matching analysis. Comparison of the serial changes in (A) PFT conduction rate, (B) ICS prescription rate, and (C) admission frequency between matched NAS-2016 and matched AS-2016. Comparison of the serial changes in (D) PFT conduction rate, (E) ICS prescription rate, and (F) admission frequency between matched NAS-2014 and matched AS-2014.

TABLE E1. Clinical characteristics, management practice, and prognosis of total asthma subjects

Variables	2013 (n = 4,386,402)	2014 (n = 4,386,764)	2015 (n = 4,362,844)	2016 (n = 4,329,248)
Clinical characteristics				
Age (y), mean $\pm$ SD	49.2 $\pm$ 18.8	50.1 $\pm$ 18.7	51.0 $\pm$ 18.6	51.7 $\pm$ 18.5
Sex: female, n (%)	2,631,797 (60.0)	2,634,277 (60.1)	2,624,373 (60.2)	2,609,017 (60.3)
Management practice, n (%)				
PFT conduction	423,080 (9.7)	456,519 (10.4)	497,786 (11.4)	523,458 (12.1)
ICS prescription	355,060 (8.1)	388,337 (8.9)	414,548 (9.5)	442,692 (10.2)
Oral steroid prescription	2,197,537 (50.1)	2,222,254 (50.7)	2,200,844 (50.5)	2,211,671 (51.1)
LTRA prescription	1,136,210 (25.9)	1,218,364 (27.8)	1,231,311 (28.2)	1,055,783 (24.4)
SABA prescription	382,623 (8.7)	370,051 (8.4)	333,930 (7.7)	287,841 (6.7)
Prognosis				
Frequency of admission for asthma per year, mean $\pm$ SD	0.018 $\pm$ 0.228	0.020 $\pm$ 0.245	0.018 $\pm$ 0.231	0.018 $\pm$ 0.241
All-cause mortality in the next year, n (%)	40,640 (0.9)	34,786 (0.8)	41,286 (1.0)	46,677 (1.1)

LTRA, Leukotriene receptor antagonist.

TABLE E2. Matching results based on age, sex, and type of institutes in the NAS-2016 and AS-2016 groups

Variable	Before matching			After matching		
	NAS-2016 (n = 3,747,833)	AS-2016 (n = 759,132)	P value	Matched NAS-2016 (n = 759,130)	Matched AS-2016 (n = 759,130)	P value
Age (y), mean $\pm$ SD	47.6 $\pm$ 18.8	52.7 $\pm$ 18.0	<.001	52.7 $\pm$ 18.0	52.7 $\pm$ 18.0	.995
Sex: female, n (%)	2,234,076 (59.6)	449,158 (59.2)	<.001	449,158 (59.2)	449,157 (59.2)	.999
Type of institutes, n (%)			<.001			>.999
Tertiary hospital	159,654 (4.3)	43,832 (5.8)		43,831 (5.78)	43,832 (5.8)	
Secondary hospital	254,613 (6.8)	70,266 (9.3)		70,269 (9.3)	70,266 (9.3)	
Hospital	155,470 (4.2)	32,590 (4.3)		32,587 (4.3)	32,589 (4.3)	
Nursing hospital	13,197 (0.4)	1,524 (0.2)		1,525 (0.2)	1,524 (0.2)	
Clinic	3,117,304 (83.2)	599,703 (79.0)		599,702 (79.0)	599,702 (79.0)	
Public health clinic, branch office, center, and others	47,595 (1.3)	11,217 (1.5)		11,216 (1.5)	11,217 (1.5)	

TABLE E3. Serial changes in management practice and prognosis of matched NAS-2016 group

Variables	2013	2014	2015	2016	2017
Management practice					
PFT conduction rate	10.0%	10.5%	11.0%	9.6%	9.1%
ICS prescription rate	6.6%	7.0%	6.8%	5.0%	4.9%
Oral steroid prescription rate	49.9%	50.1%	49.2%	47.4%	45.9%
LTRA prescription rate	25.2%	26.6%	25.9%	17.9%	17.0%
SABA prescription rate	3.3%	3.2%	3.0%	2.3%	2.1%
Prognosis					
Frequency of admission for asthma per year, mean $\pm$ SD	0.016 $\pm$ 0.216	0.018 $\pm$ 0.231	0.015 $\pm$ 0.216	0.011 $\pm$ 0.214	0.011 $\pm$ 0.201
All-cause mortality in the next year	1.4%	1.2%	1.5%	1.2%	1.0%

LTRA, Leukotriene receptor antagonist.

TABLE E4. Serial changes in management practice and prognosis of matched AS-2016 group

Variables	2013	2014	2015	2016	2017
Management practice					
PFT conduction rate	15.3%	17.5%	21.2%	31.3%	22.5%
ICS prescription rate	18.4%	21.2%	25.2%	38.5%	28.4%
Oral steroid prescription rate	52.2%	53.7%	55.5%	67.1%	55.6%
LTRA prescription rate	29.7%	33.9%	39.1%	55.5%	38.5%
SABA prescription rate	9.4%	9.9%	11.0%	14.8%	10.8%
Prognosis					
Frequency of admission for asthma per year, mean $\pm$ SD	0.035 $\pm$ 0.303	0.040 $\pm$ 0.327	0.041 $\pm$ 0.328	0.056 $\pm$ 0.382	0.046 $\pm$ 0.391
All-cause mortality in the next year	NA	NA	NA	1.5%	1.3%

LTRA, Leukotriene receptor antagonist; NA, not available (subjects were enrolled in 2016; therefore, mortality must be 0.0% in these years).

TABLE E5. Matching results based on age, sex, and type of institutes in the NAS-2014 and AS-2014 groups

Variable	Before matching			After matching		
	NAS-2014 (n = 3,747,833)	AS-2014 (n = 759,132)	P value	Matched NAS-2014 (n = 759,130)	Matched AS-2014 (n = 759,130)	P value
Age (y), mean $\pm$ SD	47.2 $\pm$ 18.7	54.4 $\pm$ 17.8	<.001	54.4 $\pm$ 17.8	54.4 $\pm$ 17.8	.996
Sex: female, n (%)	2,184,756 (59.3)	497,222 (60.7)	<.001	497,220 (60.7)	497,220 (60.7)	>.999
Type of institutes, n (%)			<.001			>.999
Tertiary hospital	155,878 (4.2)	47,480 (5.8)		47,481 (5.8)	47,480 (5.8)	
Secondary hospital	246,049 (6.7)	78,479 (9.6)		78,479 (9.6)	78,479 (9.6)	
Hospital	153,164 (4.2)	34,746 (4.2)		34,744 (4.2)	34,745 (4.2)	
Nursing hospital	11,941 (0.3)	2,774 (0.3)		2,772 (0.3)	2,774 (0.3)	
Clinic	3,071,678 (83.3)	643,482 (78.6)		643,482 (78.6)	643,480 (78.6)	
Public health clinic, branch office, center, and others	46,941 (1.3)	11,810 (1.4)		11,810 (1.4)	11,810 (1.4)	

TABLE E6. Serial changes in management practice and prognosis of matched NAS-2014 group

Variables	2013	2014	2015	2016	2017
Management practice					
PFT conduction rate	9.8%	8.8%	11.7%	12.6%	10.4%
ICS prescription rate	5.9%	4.6%	7.0%	8.2%	6.5%
Oral steroid prescription rate	49.2%	47.0%	49.2%	49.9%	46.3%
LTRA prescription rate	23.7%	20.6%	25.6%	22.6%	18.5%
SABA prescription rate	3.1%	2.3%	3.1%	3.4%	2.5%
Prognosis					
Frequency of admission for asthma per year, mean $\pm$ SD	0.016 $\pm$ 0.218	0.014 $\pm$ 0.219	0.015 $\pm$ 0.213	0.016 $\pm$ 0.232	0.014 $\pm$ 0.230
All-cause mortality in the next year	1.8%	1.0%	1.2%	1.5%	1.6%

LTRA, Leukotriene receptor antagonist.

TABLE E7. Serial changes in management practice and prognosis of matched AS-2014

Variables	2013	2014	2015	2016	2017
Management practice					
PFT conduction rate	17.2%	25.3%	19.1%	18.7%	18.4%
ICS prescription rate	20.5%	29.9%	23.3%	22.0%	21.4%
Oral steroid prescription rate	55.2%	66.4%	54.5%	53.3%	52.4%
LTRA prescription rate	35.6%	57.6%	38.4%	31.9%	31.2%
SABA prescription rate	10.2%	13.2%	9.9%	9.3%	8.8%
Prognosis					
Frequency of admission for asthma per year, mean $\pm$ SD	0.044 $\pm$ 0.348	0.062 $\pm$ 0.414	0.046 $\pm$ 0.396	0.043 $\pm$ 0.413	0.041 $\pm$ 0.402
All-cause mortality in the next year	NA	1.5%	1.6%	1.7%	1.4%

LTRA, Leukotriene receptor antagonist; NA, not available (subjects were enrolled in 2014; therefore, mortality in 2013 must be 0.0%).

TABLE E8. Comparison of the management practice and prognosis of subjects with asthma according to the type of clinics attended in NAS-2016

Variables	Subjects who visited the "good" clinics (n = 48,538)	Subjects who visited the "not-good" clinics (n = 2,594,120)	P value
Clinical characteristics			
Age (y), mean $\pm$ SD	46.8 $\pm$ 17.8	50.5 $\pm$ 18.5	<.001
Sex: female, n (%)	25,969 (53.5)	1,540,421 (59.7)	<.001
Management practice, n (%)			
PFT conduction	2,586 (5.3)	183,988 (7.1)	<.001
ICS prescription	3,046 (6.3)	104,447 (4.0)	<.001
Oral steroid prescription	12,602 (26.0)	1,204,044 (46.4)	<.001
LTRA prescription	5,905 (12.2)	437,172 (16.9)	<.001
SABA prescription	1,104 (2.3)	55,836 (2.2)	<.001
Prognosis			
Frequency of admission for asthma per year, mean $\pm$ SD	0.001 $\pm$ 0.098	0.010 $\pm$ 0.215	<.001
All-cause mortality in the next year, n (%)	215 (0.44)	26,326 (1.01)	<.001

LTRA, Leukotriene receptor antagonist.