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Prescribing antibiotics prudently—A survey of policy implementation drivers among physicians and veterinarians

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ABSTRACT

Background: As the antimicrobial resistance (AMR) problem accelerates, humans and animals are suffering from the consequences of infections with diminishing antimicrobial treatment options. Within the One Medicine and One Health mandate, which denotes a collaborative, multisectoral, and transdisciplinary approach to improve medicine and health across human and animal sectors, we investigate how human and veterinary medical practitioners apply their medical and policy knowledge in prescribing antimicrobials. Different regions and locations establish different intermediary policies and programs to support clinicians in that pursuit. In Hong Kong, there are locally adapted programs at governance and clinical levels in the human medical field. However, there is no locally adapted veterinary antibiotic prescription guideline or stewardship program, and veterinarians adopt overseas or international professions' antimicrobial use guidelines. Such a policy environment creates a natural experiment to compare local policy implementation conditions and clinicians' knowledge, perception, and practice.

Method: We construct the investigative survey tool by adaptation of Knowledge, Attitude, and Practice (KAP) and Capacity, Opportunity, and Motivation-Behavior (COM—B) models. We identify, compare and contrast factors that influence clinicians' antimicrobial prescription behavior. The factors are considered both intrinsically, such as personal attributes, and extrinsically, such as societal and professional norms.

Findings: The absence of locally adopted antimicrobial guidelines influences AMR stewardship program implementation in local Hong Kong veterinary community. As medical allies, physicians and veterinarians share similar demographic influence, organization considerations and perception of public awareness. Both cohorts prescribe more prudently with more years-in-practice, time available to communicate with patients or caretakers, and public awareness and support.

1. Introduction

Antimicrobial treatment failure will dial medicine back to a pre-antibiotic era, which saw a high mortality rate associated with bacterial infections. In the last decade, there are a number of antimicrobial resistance (AMR) policies formulated at the international, national and local levels [1–3]. These policies describe five approaches to mitigate AMR, including AMR and antimicrobial use (AMU) surveillance [4], public awareness and education [5], infectious disease prevention and control [6], innovation of AMR medicine and prevention [7], and reduction in AMU [3]. In the latter-most pursuit, physicians and veterinarians are clinicians who can gatekeep and reduce antibiotic use in the human and animal sectors respectively. To better understand the prescription behavior, contemporary studies have explored knowledge, attitude, and practice (KAP) among physicians and veterinarians [8,9]. However, local adaptation and policy implementation remain challenging [10,11]. Some challenges at the policy implementation levels are formulating effective policies, integrating clinical evidence with

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policy, and ensuring policy fidelity at clinics and farms [12,13]. For example, does antibiotic auditing policy reflect the implementation alignment between policy and clinical programs [14]? Though understanding of factors among front-line physicians [15] and veterinarians [16] do not solve all problems, some of the nuanced detail in how and what factors influence policy implementation at the clinical level can support policy alignment and re-alignment, as well as policy formulation and implementation plannings [17].

AMR intervention advocacy, formulation and implementation requires support from antimicrobial prescribers [18]. An antimicrobial stewardship program also requires integration of antimicrobial prescription behavioral factors [19]. In fact, interventions that directly or indirectly address clinicians' challenges increases policy feasibility and fidelity [20]. In addition to clinicians' inherent conditions, studies conducted in locations such as Cambodia, China, and the European Union indicated consumer, patients and public norm influence antimicrobial prescription behavior in physicians [21,22]. From these studies, the perception, attitude and behavior of prescribers are influenced by multiple factors. Assuming adequate pharmacological and clinical knowledge, clinicians' personal attributes such as self-perceived professional role as antimicrobial gatekeeper [23] and capacity to communicate with patients are intrinsic to clinicians [16,24,25]. Extrinsic to clinicians, social norms and consumer behavior also influence clinicians' prescription [26].

Understanding the nuanced detail of these factors helps translate evidence from clinical practices and research to policy and program implementation [27,28]. Some of the important detail rests in understanding the types of factors and how these factors influence clinicians' decision-making and behavior in their clinical practices [29]. Contemporary investigators look at some of these details using the KAP model [30]. In the KAP model, “knowledge” is a factor that influence “attitude”, and “practice” [30]. We adopt the KAP model as the framework for antimicrobial prescription investigation. In addition, we extend investigation by adopting variables in the COM-B model similarly to study designs in groups in Ireland and United Kingdom in human and animal sectors [16,31,32]. The “Capacity” domain in COM-B model includes knowledge from KAP model and it expands to include factors such as leadership skills and self-perceived competence in following through AMR policies. “Opportunity” domain in COM-B model includes enablers and challenges clinicians perceived and experienced in clinical practice such as patients' requests, concern for reputation of effective prescription, and defensive medicine [29,33]. “Motivation” domain includes incentives and dis-incentives that common factors in policy implementation [34]. In more than two dozens of systematic review on AMR and other public health issues, a critical and less clarified domain is what and how knowledge of the AMR policy itself influence prescription practices—a common challenge in program implementation. This study integrates the COM-B with the KAP model to study the capacities, opportunities and motivation factors among clinicians in both the human and animal sectors.

2. Materials and methods

2.1. Questionnaire design and survey

A questionnaire was administered in English. The questionnaire was comprised of 40 questions for physicians and 39 questions for veterinarians—one question on local antimicrobial guideline use was omitted for a veterinarian as there were no local guidelines. Questions were formulated to ascertain factors in prescription knowledge, demographics characteristics, enablers, and challenges associated with prudent prescription. Survey questions were adopted from reviews of AMR KAP studies [9,35,36], constructs of behavioral and social theories [37,38]. For demographics, five questions were asked regarding practice setting, clinical roles, years-in-practice, and AMR policy advisory roles. The questionnaire listed nine disease symptoms to ascertain clinical scenarios that were most likely associated with the antimicrobial prescription. For knowledge, three questions assessed knowledge of AMR, AMR policy, and AMR legal-binding policy. Four questions were asked to assess respondents' perception of the usefulness of the policy, nine questions on enablers, and seven questions on deterrents around the implementation of AMR policy. On policy use opportunities, four questions ascertained clinicians' perception regarding enablers, and four questions on whether program, resources, goal definition, or antimicrobial use parameter were available to support such endeavor. In addition to the short text space for the “others” entry, seven empirical factors that could influence prescription were listed and reported by the adapted Likert scale from “not at all important” to “extremely important.”

Delay and de-escalation of antimicrobial prescription were considered “prudent prescription writing behavior and practice” [39,40]. In addition, social, organizational, and clinical factors associated with prudent prescription writing, AMR stewardship program's implementation, knowledge, attitude and perception of antimicrobial policies, were scored based on an adapted Likert Scale and categorical responses.

The questionnaire was developed based on the KAP and Capacity, Opportunity and Motivation-Behavior (COM—B) models [41]. Physicians and veterinarians received the same questions on all except 5 demographic and practice-related questions due to difference in the nature of their practice. Two clinical vignettes were used to assess two main concepts in antibiotic stewardship—delay and de-escalate antimicrobial prescription [42,43]. To investigate delayed prescription, uncomplicated Influenza viral respiratory tract infections in human and uncomplicated Distemper viral infections in animals were postulated as viral infection clinical vignettes. Respondents would wait-and-see or delay antibiotic prescription as part of their antibiotic stewardship strategy. To investigate de-escalate prescription, superficial bacterial dermatitis was posited as a clinical vignette in the investigation of antibiotic prescription de-escalation. Combined delayed and de-escalation of antimicrobial prescription indicated prudent antimicrobial approaches.

To check the comprehensibility and clarity of the questions, pilot tests were conducted with two physicians and a veterinarian.

2.2. Sample size calculation

Sample size was calculated by z-score, squared and multiplied by p (1-p) divided by d squared; where p is expected proportion in population, z = 1.96 was set at 5% type 1 error, and d was absolute error or precision. Proportion of clinicians who had AMR knowledge was postulated to be 90% [44]. The absolute error was set at 5% and at type 1 error of 5%. The sample size was calculated to be 139 (z-score 1.96).

2.3. Participant recruitment

Clinic-by-clinic invitations were conducted per addresses outlined in the Primary Care Directory under the Health Bureau (www.pcdirectory.gov.hk) and registered veterinary surgeons (www.vsbhk.org.hk) with clinics address that were on the island. The survey was conducted between January and July 2022.

2.4. Data collection

Participants' responses were transferred from paper-questionnaire to Microsoft Excel 7 (Microsoft Corporation, Redmond, WA) spreadsheets.

2.5. Analysis

Analyses and Cronbach's alpha coefficient were conducted using SPSS (IBM SPSS Statistics 28.0.1.0).

Descriptive percentages and Fisher's exact test findings were used to

compare and contrast prescription practices between physicians and veterinarians. Association between implementation factors (continuous education, leadership, role clarity etc) and antimicrobial prescription behavior scores were investigated by univariate analysis. Fisher's exact tests were applied on factors defined as "challenges" and "enablers" to test their strength of association with prudent prescription practice.

We developed an AMR policy knowledge survey tool. To consolidate findings, we categorized factors according to the Narrative Policy Framework (NPF). In NPF, intrinsic factors such as personal expectations were categorized as factors at micro-level, governance and organizational resources at meso-level, and factors such as social norm at macro-level [45,46]. Furthermore, we applied NPF to explore the logistic regression association of antimicrobial stewardship implementation factors and prudent prescription and its use for AMR policy implementation model.

3. Results

3.1. Responses

A total of 150 invitations were sent and 102 questionnaires were completed and collected. There were 71 physicians and 31 veterinarians who completed the paper-based questionnaires. All respondents completed at least 38 out of 40 questions (Questionnaire for human sector) and 37 out of 39 questions (Questionnaire for companion animal sector) and were included in the data analysis.

3.2. Questionnaire internal reliability

The Cronbach alpha coefficient for "Challenges to use AMR policy" and "Enabler to use AMR policy" in the questionnaire were calculated. "Challenges to use AMR policy" included seven closed-ended questions and Cronbach alpha coefficient was calculated to be 0.79. "Enablers to use policy" included nine closed-ended questions and Cronbach alpha coefficient was calculated to be 0.84. "Challenges" and "Enablers" variables were derived from thematic derivatives of literature review on behavioral studies regarding deterrents and enablers on AMR policy implementation and COM—B. Both coefficient supported a reasonable internal consistency of the questionnaire (Table 1).

3.3. Respondents' demographics and disease scenarios that commonly prompted for antibiotics

Among physicians, about half of the respondents were specialists (41/71, 58%), and half were non-specialists (30/71, 42%). Few (2/71, 3%) provided emergency care, while the majority of the respondents (69/71, 97%) provided non-emergency care. Surgeons constituted 11/71 (15%) of respondents. One quarter of (18/71, 25%) of physicians practiced in hospitals only, while almost all (70/71, 99%) practiced in both clinics and hospitals. Only a minority of physician respondents engaged in administration or managerial roles (4/71, 4%). Veterinarians who responded were private companion small animal clinical practitioners. About one-tenth (4/31, 13%) of respondents regarded themselves as senior veterinarians and the same percentage practiced in hospitals. Most veterinarians (27/31, 87%) practiced in clinics (Table 2).

Physician and veterinarian respondents reported different antibiotic prescription patterns. More than half of the physician respondents indicated preference to prescribe antibiotics for surgery prophylaxis (32/52, 62%), wound treatment (36/62, 58%), urinary diseases (33/53, 63%). They were less likely to prescribe for respiratory (37%) and skin diseases (36%). In contrast, veterinarians commonly prescribed

Table 1
Clinicians' challenges and enablers regarding AMR policy use.

		Variables	Missing response	Responses					
				Veterinarians			Physicians		
		Challenges		Has been a problem	Some problem	Not a problem	Has been a problem	Some problem	Not a problem
VM20	M21	Challenge-Lack of guidelines or Lack of operational structure for guidelines	1	6	15	10	21	37	12
VM21	M22	Challenge-Lack of financial incentives	0	4	4	23	10	19	42
VM22	M23	Challenge-Lack of leadership to initiate	2	5	13	13	17	30	22
VM23	M24	Challenge-My role is unclear	1	5	7	19	12	27	31
VM24	M25	Challenge-Lack of time during consultation or work	0	6	14	11	8	25	38
VM25	M26	Challenge-Lack of autonomy	1	4	8	19	4	20	46
VM26	M27	Challenge-High concern for legal repercussion of not prescribing antimicrobials	1	2	13	15	11	41	19
		Enablers		**Would help a lot**	**Would help some**	**No helpful**	**Would help a lot**	**Would help some**	**Not helpful**
VM29	M30	Enabler-Policy support that are relevant to work settings	1	10	17	3	33	33	5
VM30	M31	Enabler-Legislative support accreditation, land use, drug import policies	1	8	17	5	12	38	21
VM31	M32	Enabler-Professional support such as guideline provision	1	19	10	2	44	24	2
VM32	M33	Enabler-Institutional support in workplace guideline and policy	2	10	13	8	35	28	6
VM33	M34	Enabler-Peer support in guideline and implementation	1	11	13	7	20	41	9
VM34	M35	Enabler-Public support in public awareness and community norms	0	19	7	5	39	24	8
VM35	M36	Enabler-Carer/client/patient awareness and cooperation with professionals	0	20	6	5	37	28	6
VM36	M37	Enabler-More time available during consultation to explain de-escalation	1	11	10	9	22	37	12
VM37	M38	Enabler-Training and continue education for staff and clinicians	2	12	15	3	27	39	4

Table 2
Practice specialties, work settings, years in practice, empirical use preference and first-line antibiotics use among physicians and veterinarians.

Physicians			*Veterinarians*		
Practice specialties			Practice specialties		
General practice/ specialist	**No.**	**%**	***Principal***	**No.**	**%**
Specialists	41	58	Principal veterinarian	4	13
Non-specialists	30	42	Non-principal veterinarian	27	87
Emergency practice			***Sole practice***		
Non-emergency physicians	2	3	Sole-in-charge veterinarian	8	26
Emergency physicians	69	97	Multi-veterinarian practice	23	74
Surgeons			***Seniority***		
Surgeons	11	15	Senior veterinarian	16	52
Non-surgeons	60	85	Non-senior veterinarian	15	48
Non-clinical role-administration			***Non-clinical role***		
Administrators	2	3	Academic	0	0
Non-administrators	69	97	Managerial	0	0
			Pharmaceutical	0	0
Management					
Managerial role	1	1			
Non-managerial role	70	99			
Practice settings			**Practice settings**		
Work settings	**No.**	**%**	***Work settings***	**No.**	**%**
Clinics and hospitals	70	99	Hospitals	4	13
Others (did not specify)	1	1.4	Clinics	27	87
Hospital residency					
Hospital-visiting physicians	6	8			
Hospital-resident physicians	65	92			
Years in practice			**Years in practice**		
	No.	**%**		**No.**	**%**
0–5 years	6	8.5	0–5 years	6	19
6–19 years	27	38	6–19 years	21	68
>20 years	38	54	>20 years	4	13
Preference in empirical antibiotic use in viral infection			**Preference in empirical antibiotic use in viral infection**		
	No.	**%**		**No.**	**%**
Empirical antibiotics use	10	14	Empirical antibiotics use	6	19
Other treatment	52	74	Other treatment	17	55
No treatment	5	7.1	No treatment	0	0
Other response	3	4.3	Other response	8	26
First-line antibiotics use			**First-line antibiotics use**		
	No.	**%**		**No.**	**%**
Narrow-spectrum antibiotics	7	11	Narrow-spectrum antibiotics	0	0
Broad-spectrum antibiotics	18	28	Broad-spectrum antibiotics	10	32
Start with narrow-specturm but subject to changes	29	45	Start with narrow-specturm but subject to changes	5	16
Start with broad-specturm but subject to changes	11	17	Start with broad-specturm but subject to changes	12	39
Others	0	0	Others	4	13

antibiotics for wounds (23/31, 74%), skin diseases (19/31, 61%) and respiratory diseases (20/31, 65%), urinary diseases (61%) and to lesser extent for surgery prophylaxis (39%) (Table 3).

Likeliness of empirical antibiotic prescription in diseases with less defined etiology was investigated. On a Likert scale of antibiotic prescription likeliness that ranged from "always" to "never", symptoms with fever of unknown origin prompted 23% of physicians and 32% of veterinarians to prescribe antibiotics. Approximately 33% of veterinarians "frequently" or "always" prescribe antibiotics for gastro-intestinal diseases. In contrast, 48% of physicians never prescribe antibiotics for gastro-enteral conditions. Of patients with anorexia, 98% of physicians (35/42) and 74% of veterinarians (23/31) "rarely" or "never" prescribed antibiotic (Table 3).

3.4. Knowledge of AMR, de-escalation approach and AMR policy

In terms of AMR knowledge, the majority (68/71, 96% and 30/31, 97%) of physician and veterinarian respondents came across antimicrobial resistance terminology, and about one-fifth of respondents (12/71, 17%, and 6/34, 19%) had antimicrobial stewardship program (AMSP) in their work setting. A similar percentage of respondents in both cohorts perceived resources (14/71, 19% and 5/31, 16%), protocol provision (15/70, 21% and 8/31, 26%), and AMR peer-benchmarking (5/71, 7% and 5/31, 10%) important to their AMR program implementation. About 16% (11/71) of physician respondents and 26% (8/31) of veterinarian respondents indicated they knew legal- or non-legal binding government and clinician policies. Regarding work settings, prescription perceptions were not influenced by work settings among physicians. There was no statistically significant difference in prescription behavior among GPs and non-GPs, or between visiting and resident physicians working in hospitals (Fisher's exact test, p-value>0.05).

Though years-in-practice differed between physicians and veterinarians, both cohorts demonstrated statistically significant association between "years-in-practice" and prudent prescription behavior. About half of the physician (38/71, 54%) and one-tenth of veterinarian (4/31, 13%) respondents were in practice for over 20 years. A higher proportion (21/31, 68%) of veterinarians were in their profession for 6 to 19 years compared to physicians (27/71, 38%). Using a minimum of 5 years in practice as an arbitrary cut-off, Fisher's exact test indicates years-in-practice was significantly associated with prudent antimicrobial prescription for physicians and veterinarians (Fisher's exact test value 0.011 and 0.049, p-value<0.05). The more years in practice the more prudent prescription writing.

Delay and de-escalation are essential approaches in AMR stewardship programs. This means clinicians have to hold-off writing prescriptions of antibiotics, use narrow-spectrum antibiotics instead of broad-spectrum antibiotics, and change antibiotics from intravenous to oral formulation. Physician and veterinarian respondents behaved similarly in terms of delay of antibiotics prescription in two main scenarios. Their behavior to delay prescribing antibiotics to patients who do not present with symptoms with bacterial infections was independent of the respondents' knowledge of AMR policy strategies (Table 4). Among human physicians, 14% considered prescribing empirical antibiotics, while 74% responded they would not prescribe empirical antibiotics and instead chose other treatment approaches. Under the same circumstance, 19% of veterinarians considered empirical antibiotics prescription, while 55% would not prescribe antibiotics but instead chose other treatment approaches (Table 2).

There were statistically significant differences between physician and veterinarian respondents in their antibiotic de-escalation approaches (Table 4). Among physician respondents, 11% preferred narrow-spectrum antibiotics for the whole course of treatment, and 28% preferred broad-spectrum antibiotics for the whole course of treatment. About half of the respondents (45%) preferred narrow-spectrum antibiotics and change if symptoms did not improve. In the same medical scenario, no veterinarian respondents preferred narrow-spectrum antibiotics for the whole course of treatment, 16% preferred to prescribe narrow-spectrum and change if symptoms did not improve, 32% broad-spectrum antibiotics for the whole course of treatment, and 39% broad-spectrum antibiotics and changed if symptoms did not improve (Table 2).

3.5. Challenges and enablers to implement antimicrobial stewardship policy and programs

Both physicians and veterinarians perceived pre-clinical, clinical training and disease diagnostics as enablers for adopting prudent antibiotic prescription writing practices. Physicians perceived knowledge

Table 3
Physicians' and veterinarians' responses on antibiotic prescription likeliness.

Clinicians' response regarding disease condition and antibiotic prescription likeliness							
	Physician responses on diseases and antibiotics prescription likeliness						
Disease condition	**Never**	**Rarely**	**Sometimes**	**Frequently**	**Always**	**Did not respond**	**Respond to question**
Skin disease	11	**14**	**21**	**6**	6	13	58
Gastro-enteral disease	**24**	**17**	**2**	**4**	2	22	49
Respiratory disease	**9**	**5**	**19**	**15**	3	20	51
Urinary disease	**7**	**3**	**10**	**21**	12	18	53
Dental disease	**16**	**9**	**7**	**10**	3	26	45
Surgery prophylaxis	**9**	**5**	**6**	**12**	20	19	52
Wounds	**8**	**3**	**15**	**19**	17	9	62
Fever of unknown origin	**12**	**10**	**11**	**7**	7	24	47
Anorexia	**35**	**6**	**0**	**1**	0	29	42
	Veterinarian responses on diseases and antibiotics prescription likeliness						
Disease condition	**Never**	**Rarely**	**Sometimes**	**Frequently**	**Always**	**Did not respond**	**Respond to question**
Skin disease	1	2	9	17	2	0	31
Gastro-enteral disease	1	5	14	9	2	0	31
Respiratory disease	1	1	9	16	4	0	31
Urinary disease	1	2	19	7	2	0	31
Dental disease	1	4	11	10	5	0	31
Surgery prophylaxis	0	8	12	7	4	0	31
Wounds	1	0	7	11	12	0	31
Fever of unknown origin	1	7	10	7	6	0	31
Anorexia	10	13	6	0	2	0	31

Table 4
Analysis of the difference between antimicrobial practices and prescribing behavior between physicians and veterinarians.

Different factors associated with prudent prescription between physicians and veterinarians	Z-value	p-value	Significance
AMR prudent prescription policy knowledge*	−2.7474	0.003	Significant difference
Narrow spectrum antibiotics as first-line medication (De-escalation approach)	2.6109	0.009	Significant difference
AMU in viral infected patients	−1.8271	0.07	No difference
AMR policy use	0.2012	0.8	No difference
Prudent antimicrobial prescription behavior**	0.9777	0.3	No difference

* Policy knowledge is defined as legal or non-legal policy knowledge.
** Prudent antimicrobial prescription behavior is defined as de-escalated and delayed prescription.

acquired at medical school (OR = 8.4, *p*-value = 0.015) and laboratory results (OR = 24.6, p-value<0.0005) important and were statistically significantly associated with adequate delay and de-escalation of antimicrobial prescription (Table 5). In contrast, physicians who include patients' or caretakers' requests for antimicrobials were negatively associated with prudent prescriptions (OR = 0.13, P-value = 0.011). There was no statistically significant association between factors and prudent prescription writing among veterinarians (Table 5). Though unable to calculate statistical association, patients' laboratory test results were perceived as an important variable to prescribe antimicrobials by 29/30 (97%) of veterinarians.

Among respondents who were physicians, the majority (58/70, 82.9%) perceived the lack of operational structure, defined as stewardship program or guidelines implementation structures in hospitals, clinics, and pharmacies, as problematic. Physicians also perceived legal repercussions (fear of not using antibiotics promptly) to delay or de-escalate antibiotic prescriptions as a hurdle to implementing AMR guidelines (52/71, 73.2%). When asked about other implementation challenges, in descending order, respondents perceived a lack of leadership to implement AMR policies (47/69, 68.1%), clear personal role (39/70, 56%), time to consult with patients (33/71, 46.5%), financial incentives (29/71, 40.9%), and autonomy in prescription (24/70, 34.3%) as problematic (Fig. 1).

Among veterinary respondents, the most commonly perceived policy implementation challenge was the lack of local veterinary medical antimicrobial use guidelines (21/31,67.8%), followed by lack of time in consultation (20/31, 64.6%), lack of leadership (18/31, 58.0%), and concern for legal repercussion for not prescribing (15/30, 50%). Respondents did not perceive a lack of autonomy in prescription (12/31, 38.7%), undefined or unclear personal role (12/31, 38.7%) in AMR mitigation, or financial incentives (8/31, 25.8%) as problematic (Fig. 1).

Physician respondents perceived availability of clinical practice and locally-adopted antimicrobial prescription guidelines (68/70, 97.1%) as the most helpful support to implement AMR policies (defined as antimicrobial prescription or use guidelines). Enablers that improved policy implementation also include training and continuous education (66/70, 94.3%) (defined as continuous medical education or clinician development), and policy support (66/71, 93.0%) (defined as applicable policy formulated and adopted) (Fig. 2). Patient support (65/71, 91.5%) (defined as patient awareness and cooperation with clinicians who advised withholding or de-escalation of antimicrobial prescription) and institutional support (63/69, 91.3%) (defined as work setting stewardship program) were also enablers to implement AMR policies. Respondents considered legislation, defined as regulatory, service provision, and fiscal policies (50/71, 70.4%) as policy implementation enablers but to lesser extent (Fig. 2).

Similar to physicians, veterinarian respondents perceived the most helpful way for policy to support prudent prescription writing was clinical practice and locally-adopted antimicrobial prescription guidelines (29/31, 93.6%), followed by training and education (27/30, 90.0%), and policy alignment (27/30, 90.0%) (Fig. 2). The majority of respondents (26/31, 83.9%) considered animal caretaker and client support (defined as caretaker and client with more awareness and cooperation when veterinarians recommend to withhold, de-escalate antimicrobial use) and public support (defined as public awareness and social norm) helpful. Other enablers of prudent prescription included legislative (25/30, 83.3%) and institutional (23/31, 74.2%) support, followed by time resource commitment during consultation (21/30, 70.0%) (Fig. 2).

Physician and veterinarian respondents opined that consultation time with patients or caretakers was critical. In addition, consultation time was statistically associated with prudent antimicrobial prescription (Fisher's exact test value 0.034, p-value<0.05). Public support, defined as public awareness and community norm that supports antimicrobial resistance stewardship policy implementation, was moderately statistically significantly associated with clinicians' prudent prescription (multiple logistic regression, *p*-value = 0.05).

Table 5
Perception of factors' importance in antimicrobial stewardship and odds of prudent prescription among physicians and veterinarians.

Physicians	Variable	Levels	Prudent prescription (%)	Imprudent prescription (%)	OR	95 CI	p-value	*Z*-score
	Medical training & knowledge acquired at medical school	Important Influence	56	2	8.4	1.24–56.81	0.015	2.18
		Not important influence	10	3	1			
	My clinical experiences	Important Influence	59	6	NA	NA	NA	NA
		Not important influence	6	0	NA			
	Peer advice, inpurt or comment	Important Influence	37	4	1.02	0.21–4.98	0.49	0.03
		Not an influence	27	3	1			
	Continuous professional development/ continous medical education	Important Influence	58	6	1.61	0.17–15.71	0.34	0.41
		Not an influence	6	1	1			
	Material based on pharmaceutical company	Important Influence	35	3	1.17	0.22–6.21	0.42	0.18
		Not an influence	30	3	1			
	Patient's lab result	Important Influence	59	3	24.6	4.26–141.94	0.00002	3.6
		Not an influence	4	5	1			
	Patient's or patient carer's request	Important Influence	16	5	0.13	0.024–0.76	0.011	2.28
		Not an influence	48	2	1			

Veterinarian						
Variable	**Perception levels**	**Prudent prescription**	**Imprudent prescription**	**OR***	**95% CI****	**P-value**	***Z*-score**
Medical training & knowledge acquired at medical school	Important Influence	20	8	2.5	0.14–45.01	0.27	0.62
	Unimportant influence	1	1	1			
Clinical experiences	Important Influence	19	7	2.7	0.32–23.14	0.18	0.91
	Unimportant influence	2	2	1			
Peer advice, inpurt or comment	Important Influence	11	5	0.88	0.18–4.23	0.44	0.16
	Unimportant influence	10	4	1			
Continuous professional development / continous medical education	Important Influence	19	6	4.75	0.64–35.48	0.06	1.51
	Unimportant influence	2	3	1			
Material based on pharmaceutical company	Important Influence	3	0	NA***	NA***	NA***	NA***
	Unimportant influence	18	9	NA***			
Patient's laboratory result	Important Influence	21	8	NA***	NA***	NA***	NA***
	Unimportant influence	0	1	NA***			
Patient's or patient carer's request	Important Influence	3	0	NA***	NA***	NA***	NA***
	Unimportant influence	18	9	NA***			

Stewardship variables and perception of importance		**Physicians**						**Veterinarians**					
Variables in stewardship programs	**Perception**	**Prudent prescription**	**Imprudent prescription**	**OR***	**95% CI****	**p-value**	***Z*-score**	**Prudent prescription**	**Imprudent prescription**	**OR***	**95% CI****	**P-value**	**Z-score**
Medical training & knowledge acquired at medical school	Important Influence	56	2	8.4	1.24–56.81	0.015	2.18	20	8	2.5	0.14–45.01	0.27	0.62
	Unimportant influence	10	3	1				1	1	1			
Clinical experiences	Important Influence	59	6	NA***	NA***	NA***	NA***	19	7	2.7	0.32–23.14	0.18	0.91

(*continued on next page*)

Table 5 (*continued*)

Physicians	Variable	Levels	Prudent prescription (%)	Imprudent prescription (%)	OR	95 CI	p-value	*Z*-score	**Veterinarian**					
		Unimportant influence	6	0	NA***				2	2	1			
	Peer advice, inpurt or comment	Important Influence	37	4	1.02	0.21–4.98	0.49	0.03	11	5	0.88	0.18–4.23	0.44	0.16
		Unimportant influence	27	3	1				10	4	1			
	Continuous professional development / continous medical education	Important Influence	58	6	1.61	0.17–15.71	0.34	0.41	19	6	4.75	0.64–35.48	0.06	1.51
		Unimportant influence	6	1	1				2	3	1			
	Material based on pharmaceutical company	Important Influence	35	3	1.17	0.22–6.21	0.42	0.18	3	0	NA***	NA***	NA***	NA***
		Unimportant influence	30	3	1				18	9	NA***			
	Patient's laboratory result	Important Influence	59	3	24.6	4.26–141.94	0.00002	3.6	21	8	NA***	NA***	NA***	NA***
		Unimportant influence	4	5	1				0	1	NA***			
	Patient's or patient carer's request	Important Influence	16	5	0.13	0.024–0.76	0.011	2.28	3	0	NA***	NA***	NA***	NA***
		Unimportant influence	48	2	1				18	9	NA***			

*OR: Odds ratio.
** CI: Confidence Interval.
NA***: No case for calculation of OR.

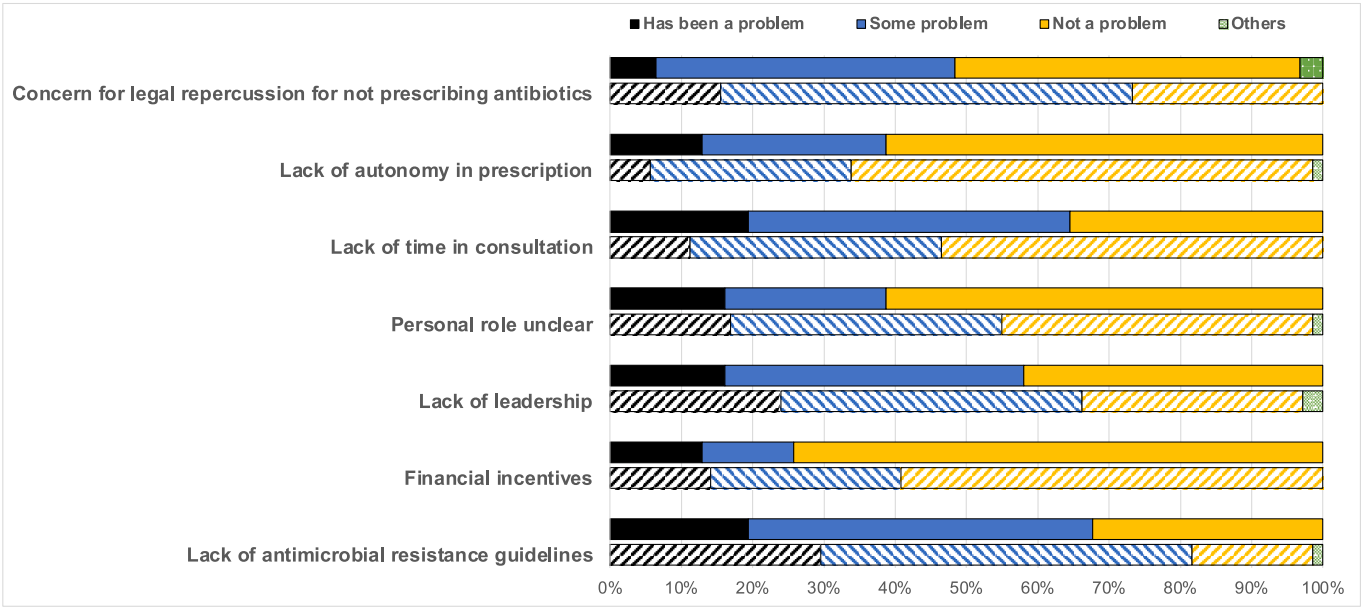

Fig. 1. Perceived challenges to implement prudent antimicrobial prescription among physicians and veterinarians. Solid bars represent veterinarians' responses, and patterned bars represent physicians' responses. The relative length of the bars is indicative of responses.

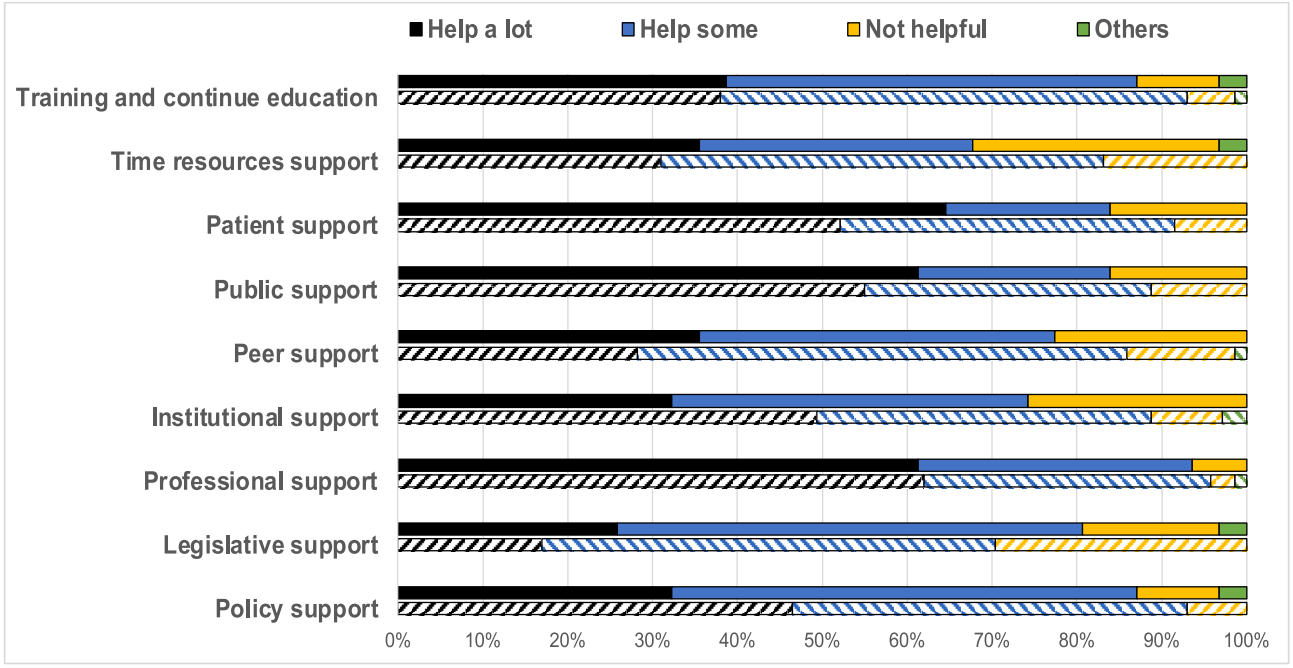

Fig. 2. Enablers to implement antimicrobial resistance policies among physicians and veterinarians. Solid bars represent veterinarians' responses, and pattern bars represent physicians' responses. The relative length of the bars is indicative of responses.

4. Discussion

The World Health Organization depicts One Health as an integrated and unifying approach to sustainably balance and optimize the health of people, animals and environment (www.who.int). The problem of antimicrobial resistance sits squarely in the One Health paradigm as solving the problem of AMR requires collaboration, multi-sectoral and transdisciplinary approach at local, regional and global levels (www.cdc.gov). At a local level, this study provides an assessment of the main enablers and challenges at the multi-sectoral domain of Hong Kong physicians and veterinarians. This study provided an assessment of the main enablers and challenges among Hong Kong physicians and veterinarians to prudently prescribe antimicrobials. Results suggested pre-clinical training and years-in-practice are associated with prudent prescription practices. Respondents also considered consultation time a critical factor associated with good prescription practice. The public's support for clinicians' intention to de-escalate antimicrobial prescription was perceived to be essential. These variables pointed to significance in pre-clinical education, clinical continuous education, governance of clinical consultation in terms of time allowed to communicate with patients, public awareness program and patient education. This was supported by study that suggests years-in-practice is positively associated with knowledge score [47].

The second Hong Kong AMR Strategic Action Plan is published. The

policies in the Action Plan focus on programs to reduce antimicrobial use. The policy intention was an excellent segue to look into the development of policies and interventions to improve technical and social factors on prudent antimicrobial prescription writing among clinicians. Respondents in this survey described factors such as clinical training, social norm, and patient and client education that improves implementation feasibility. In this case, Consolidated Framework for Implementation Research (CFIR) can conceptualize AMR policymaking and highlight policy inventory for AMR prudent prescription. The framework consisted of five categories that can combine study findings and policy inventory (Table 6). The most relevant category to policy implementation was summarized under "intervention characteristics". In the category was a summary of findings from data. First, physician and veterinarian students should receive pre-clinical training emphasizing delay and de-escalation of prescribing antimicrobial. Second, it was encouraging to observe low antibiotic prescriptions in the anorexia vignettes. This "no-antibiotics' approach in anorexic cases should be emphasized and promulgated in pre-clinical training. However, there was an alarmingly high prescription preference for the respiratory disease vignettes in human medicine and gastro-enteral disease vignettes in veterinary medicine. These two cases deserved further professional education on delay and de-escalation of prescription. Third, stewardship programs and antimicrobial prescription guidelines in veterinary medicine should be formulated. Fourth, as consultation time was a bottleneck to prescribe antimicrobials prudently, clinical governance and management must mediate cost-value and economic evaluation for extending consultation on antimicrobial stewardship. Strong communication capacity and time allowed to consult on prudent use of antibiotics should be considered part of the clinic accreditation.

There are cross-sectoral learning lessons between human and veterinary medical sectors. As public health and medical professionals were aware of the nature of changing and upward trends of resistance in antimicrobials, it was logical to emphasize the significance of contemporaneous clinical education, AMR reporting systems, contextual and collaborative AMR stewardship programs. Indeed, respondents emphasized locally adopted and contextual antimicrobial policies were essential for program implementation. Physicians in Hong Kong can refer to antimicrobial prescription local and international guidelines. Veterinarians in Hong Kong did not have locally-adopted AMR guidelines. Hong Kong veterinarians commonly referred to international guidelines. Comparison of policy use perceptions between physicians and veterinarians indicated veterinarians' preference of locally adopted guidelines. The precedent guidelines and policy in human medicine provides a template for veterinary medicine to refer and reflect. Similar to human medicine, veterinary medicine is catching up in terms of specialized veterinary laboratory diagnostics as an enabler to prescribe prudently. This linked to the importance of reliable and accessible laboratory diagnosis in veterinary medicine.

There are inter-disciplinary learning and discussion points from this study. In terms of AMR policy implementation as a sequel of professional knowledge, capacity and motivation, recent implementation science proposed policy to be developed for at least two functions—strategic and interventional [48]. Strategic policies are those that provide template for adoption and implementation. Interventional policies are those that provide guidelines and programs for daily implementation. In our findings, physicians were feeling at risk regarding defensive medicine when they delayed or de-escalated prescription of antibiotics. This is a clinical experience perspective that can result in strategic policy. Human and veterinary clinical perspectives also depicts necessary milestones such as improvement of diagnosis, competence, and capacity that can lead up to strategic policy. In addition, interventional policies and incentives for patients to follow up with the same physicians can help physicians monitor their patients closely so that if antibiotics was needed, it can be dispensed in time. This target required emphasis of primary care doctor concept, close communication with family doctor, and fidelity to the clinic. In addition, there is limited consultation time to explain delay or de-escalation of prescription. This consultation time requires interventional guidelines so that professional and clinic management can implement best practices and make time to explain prescription delays. According to findings from veterinarians, the lack of local AMR guidelines is a prominent gap to prescribe antimicrobial prudently. This reflects the importance for human medical sector to continue and sustain the already formulated and implemented programs; it is also important for veterinary medical sector to formulate and adopt local AMR guidelines and programs. These are One Health strategic policy learnings in which professional and government offices in human and veterinary medicine can collaborate, formulate and update their antimicrobial prescription policy.

This study was limited by its small sample size and non-randomized sampling, thus respondent bias may have occurred. However, the response rate among those invited was about 70% which was a reasonable percentage. It was also noteworthy that respondents were not as familiar with AMR policy knowledge as knowledge of AMR pharmacology and technical knowledge. Thus it would be preferrable to define policy, programs and guidelines for the respondents in future survey.

Part of this investigation focused on developing a policy survey tool to help further investigate the "Challenges" and "Enablers" in AMR policies. Upon Cronbach's alpha coefficient calculation, this tool appeared to have relatively good agreement across questions and may therefore be of reasonable use. It may be useful in terms of policy research to improve and fine-tune this questionnaire for further studies. Adequately expansion to more medical professionals could provide data points for formulation, adaptation, implementation and evaluation of

Table 6
A representation of Consolidated Framework for Implementation Research. Domain under intervention characteristics highlight the pre-clinical and clinical training aspects and local guidelines critical to prescribe antimicrobial prudently.

Consolidated Framework for Implementation Research				
Intervention characteristics	Policy subfeatures	Inner settings	Outer settings	Policy process
Improve pre-clinical training especially on delay and de-escalation of antimicrobials	Stewardship campaign	General population	Level of policy:	Governance
Improve on-job training especially on disease management of challenging cases and where antibiotics are most prescribed. This can be case management of anorexia, fever of unknown origin, respiratory diseases in human medicine, and gastroenteral diseases in veterinary medicine.	Antimicrobial use and resistance surveillance	Government administration	National, provincial, city	Information system
Local antimicrobial guideline and program for veterinary medicine	Clinic governance resources allocation	Professional community	Sectors:	Capacity building
Extended antimicrobial consultation time and communication training	Laboratory capacity building	Hospitals and veterinary clinics	Human, animal, food and feed	
Clinic accreditation with AMR protocol	Public health education among patients and animal caretakers	Farms		
		Community pharmacy and pharmaceutical industry		

AMR policy implementation.

5. Conclusion

This study focuses on the investigation of AMR policy implementation factors according to the One Health framework. We study cohorts of physicians and veterinarians, compare and contrast factors that enable or deter good antimicrobial prescription practices in the human and animal sectors. The common issues physicians and veterinarians face are to apply their technical knowledge as well as policy knowledge, implement AMR programs and guidelines to change behavior in different stakeholders, minimize the prescription of antimicrobials and use the correct bug-drug combination. This study aims to distill, consolidate and discuss factors learned from these two cohorts to explore options and adaptations in prudent antimicrobial prescription guidelines and stewardship programs.

In comparing how physicians and veterinarians consider medical knowledge, policy knowledge and social factors to prescribe or hold off antimicrobials, the two cohorts share commonalities and differences. By the nature of medicine in different species, different disease etiologies change how and what antimicrobials clinicians prescribe. There are also differences in the policy setting such as the finance of veterinary medicine, the lack of local antimicrobial guidelines in companion animal medicine and the lack of obligated prescription in farm-animal antimicrobial use.

The principle of prudent antimicrobial use and bottlenecks in policy implementation do not differ much between the animal and human sectors. The findings from this survey are mixes of intrinsic and extrinsic factors that influence antimicrobial resistance stewardship programs among physicians and veterinarians. The lack of public support and patient knowledge in antimicrobial use, lack of consultation time to explain antimicrobial de-escalation and delay and the concern for legal comeback for dormant or delayed microbial infection at the time of consultation are some of the deterrents to holding off antimicrobial use. The majority of respondents in both human and animal sectors emphasize the importance of knowledge gained as medical students preclinically and on-the-job clinical training on prudent prescription and bug-drug combination. Furthermore, respondents highlighted the significance of antimicrobial use literacy among the public and patients; as well as the continuous policy attention and locally adapted implementation of the AMR legislature and guidelines.

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Institutional review board statement

The survey complied with the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (IRB Ref. UW 18–206).

Informed consent statement

Response was voluntary, and participants were given informed consent on the questionnaire. No identities were collected, and all data remained anonymous.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

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